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PROCEEDINGS

CANPAC '88

Canadian Power Alcohol Conference

Alcohol Fuels For Transportation

INTERNATIONAL INN
WINNIPEG, MANITOBA
OCTOBER 3 AND 4, 1988

Organizers:
Biomass Energy Institute
Canadian Renewable Fuels Association
Canadian Oxygenated Fuels Association

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Ministre
de l'Énergie, des Mines et des Ressources

CANADA

Minister
of Energy, Mines and Resources

L'honorable The Honourable

Marcel Masse

Dear participants:

Welcome to the Third Canadian Power Alcohol Conference-CANPAC '88 and to the beautiful city of Winnipeg.

I am particularly pleased to see the focus of this conference on alcohol fuels and transportation. Currently in Canada, we estimate that 748,000 barrels of oil equivalents a day are used in the transportation sector. While much of this is, and will continue to be, produced from our own oilfields, past events have indicated that alternatives are necessary. The possibility of using ethanol made from grain-crop surpluses and other biomass wastes and methanol from natural gas and coal offers exciting prospects which we believe can, in the longer-term, provide cost-competitive tranportation fuels.

Coupled with this is our increased interest in protecting the environment. One area of particular concern is the use of leaded gas. By the early 1990's it is proposed that lead in gasoline be replaced by other more environmentally acceptable chemicals. Again, alcohols have exciting prospects here as clean burning gasoline additives.

In the past, governments and industry have been instrumental in developing the technical expertise to produce alcohol fuels. Although we have come a long way, this task is not yet over. Moreover, added to this is the new challenge of making such fuels or fuel additives attractive economically, not an easy task when oil is less than $20 a barrel.

Under the new Energy Efficiency and Diversity initiative, which I announced recently, my Department remains committed to R&D in the area of renewable energy and alternative transportation fuels. However, it is not governments alone which will determine whether alcohol fuels become a reality in Canada, but cooperation between governments, the research community, and the private sector.

For this reason, it gives me great satisfaction to see such a broad spectrum of interested parties represented at this conference; your various interchanges can only be positive.

Best wishes for a successful conference.

Marcel Masse

Ottawa, Canada K1A 0E4

Ministre
de l'Énergie, des Mines et des Ressources

Minister
of Energy, Mines and Resources

CANADA

L'honorable The Honourable

Marcel Masse

Chers participants et participantes,

Au cours des prochaines années, le Canada devra, pour des raisons environnementales et économiques, multiplier les sources et les modes de l'énergie qu'il consomme. C'est pourquoi je me réjouis de la tenue d'une conférence consacrée aux carburants alcoolisés dans le secteur des transports.

Parce que ses moindres échanges s'effectuent sur de vastes étendues, notre pays consomme quotidiennement dans ce secteur l'équivalent de 748,000 barils de pétrole. Sans doute nos champs pétrolifères continueront-ils encore longtemps de fournir l'essentiel de cette énergie, mais nous savons maintenant que doivent être développées d'autres options énergétiques.

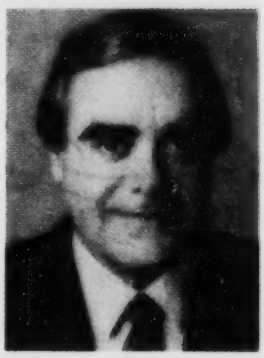
Fort heureusement, des solutions sont en vues. L'éthanol, fabriqué à partir des sous-produits céréaliers et autres matières organiques, ou le méthanol, tiré du gaz naturel, du charbon et de la biomasse, nous offrent, à terme, des carburants de transport compétitifs. Ajoutons que l'élimination du plomb comme additif à l'essence promet aux alcools un intéressant rôle supplétif.

Gouvernements et industries ont jusqu'à maintenant collaboré dans le développement des technologies de carburants alcoolisés. Les progrès accomplis sont remarquables, mais la tâche demeure d'autant plus ardue que la chute des prix du pétrole a tendance à décourager le recours aux solutions de remplacement.

Par sa nouvelle initiative d'Efficacité et de Diversité Energétique, mon ministère demeure fidèle à la recherche-développement appliquée aux énergies renouvelables et aux carburants de rechange pour les transports. La garantie de notre succès dans le domaine des carburants alcoolisés n'en continue pas moins de reposer d'abord sur la collaboration entre industries, chercheurs et administrations publiques.

CANPAC 88 réunit des spécialistes de tous ces horizons. Que cette conférence ait lieu dans l'accueillante ville de Winnipeg est une autre promesse d'excellents résultats. Je vous souhaite une rencontre fructueuse.

Marcel Masse



Ottawa, Canada K1A 0E4

PREFACE

The proceedings of the CANPAC '88 conference have been compiled from papers given to the editor, and transcription of conference tapes when papers were brief, or not available. Papers transcribed were only edited for flow and spelling.

The September Bio-Joule had introductory articles on alcohol fuels for transportation and the November Bio-Joule provided an account of the conference. Both these issues are available with the proceedings.

In some instances the charts are missing from the presentation at the request of the speaker. Please contact the author of the paper for further information.

Towards a Commercial Future: Ethanol and Methanol as Alternative Transportation Fuels, can be obtained from the Canadian Energy Research Institute, 3512 - 33 Street N.W., Calgary, Alberta, T2L 2A6, for $30 Cdn. plus 15% handling and mailing.

Changes in Gasoline and the Automobile Service Technician, can be obtained from the Renewable Fuels Foundation, Suite C-4, 201 Massachusetts Avenue N.E., Washington, D.C. 20002, USA.

Special thanks to the Manitoba Government Ministers who introduced our guest speakers at lunch. Hon. Mr. Harold Neufeld, Minister of Energy and Mines introduced Art Meyer and Hon. Mr. Ed Connery Minister of Environment, Workplace Safety and Health, introduced Tony Massaro on Tuesday.

CANPAC '88 PROGRAM

Canadian Power Alcohol Conference
Alcohol Fuels for Transportation

Monday, October 3 and Tuesday, October 4, 1988
International Inn, Winnipeg, Manitoba
Wellington at Berry, adjacent to International Airport

Sunday, October 2

P.M.

7:00 - **Registration and Reception to Welcome Delegates** (Salon 2)

Monday, October 3

A.M.

7:00 - **Registration and Information Desk Open**

8:30 - **Welcome and Opening Remarks** (Manitoba Room) - Ted Speers, Chairman, Board of Directors, Biomass Energy Institute

8:45 - **Session 1 - Policy** (Manitoba Room)

Chairman - Otto Lang, Transport Institute, Winnipeg, Manitoba
- **Canadian Federal Policy** - Tony Taylor, Energy, Mines and Resources Canada, Ottawa, Canada
- **Future Canadian Development** - Michelle Heath, Canadian Energy Research Institute, Calgary, Alberta
- **Manitoba Experience** - Al Jenkins, Renewable Fuels and Alternate Energy, Manitoba Energy and Mines, Winnipeg, Manitoba

10:15 - **Coffee Break**

10:30 - **Session 2 - Technical** (Manitoba Room)

Chairman - Ewen Coxworth, Manager, Biomass Resources, Saskatchewan Research Council, Regina, Saskatchewan
- **Mohawk Oil Co. Ltd. - Seven Years of Experience** - Don O'Connor, General Manager,Alcohol Fuels Division, Mohawk Oil Co. Ltd., Burnaby, B.C.
- **Integrated Ethanol-Cattle Feeding** - Del Shafer, Technology Distributors Int., Edmonton, Alberta
- **Extractive Fermentation and Recovery** - Andy Daugulis, Chemical Engineering, Queen's University, Kingston, Ontario

P.M.

12:00 - **Lunch with Speaker** (Salon 3)
- **The Development of Fuel Ethanol in Canada (1978-1988)** - Art Meyer, Executive Vice-President, Mohawk Oil Co. Ltd., Burnaby, British Columbia

2:00 - **Session 3 - Policy** (Manitoba Room)

Chairman - Roy Piper, Director, United Grain Growers, Elrose, Saskatchewan
- **Alberta Studies and Policy Development** - Ken Beswick, Alberta Grain Commission, Edmonton, Alberta
- **Saskatchewan - Ethanol Production and Marketing Incentive Program** - Martin Wrubleski, Saskatchewan Agriculture
- **Quebec and Alcohol Fuels** - Laurie Baker, Agriculture Economics, Macdonald College of McGill University, Ste. Anne de Bellevue, Quebec
- **Ontario Situation** - Barry Beale, Ontario Ministry of Energy, Toronto, Ontario

4:30 - 5:30 - **Biomass Energy Institute Annual Meeting** (Salon 3)
Canadian Renewable Fuels Association Meeting (Agassiz Room)

6:30 - **Reception** (Manitoba Room)

7:30 - 10:00 - **Banquet and Speaker** (Manitoba Room)
- **Oxygenated Fuels in the United States of America** - Ben Henneke, President, Energy Fuels Development Corp., Portales, New Mexico

Tuesday, October 4

A.M.

8:30 - **Session 4 - Technical** (Manitoba Room)

Chairman - Terry Daynard, Ontario Corn Producers' Association, Guelph, Ontario
- **V Plus/ Comet Stations** - Bill Hillier, Sunoco, North York, Ontario
- **An Environmentally Safe Octane Source for the Future from Co-Op: Ethanol Plus - Oxygenated Gasoline** - Glen Perschbacher, United Cooperatives of Ontario, Mississauga, Ontario
- **Perspectives on Alcohol Fuels** - Terry Daynard, Ontario Corn Producers' Association, Guelph, Ontario

10:15 - **Coffee Break**

10:30 - **Session 5 - Perspectives** (Manitoba Room)

Chairman - Bob Charles, Maintenance Systems Engineer, Winnipeg Transit, Winnipeg, Manitoba
- **The Alcohol Dilemma** - Tom Hamilton, Materials Engineer, Chrysler Canada, Windsor, Ontario
- **Environmental Perspective** - Chandra B. Prakash/C. Wachmann, Environment Canada, Ottawa, Canada
- **Effects of Changes in Gasoline on Automobiles** - Bob Schwandt, Retired Vice President, Ethanol Sales, Staley's, Knoxville, Tennessee

P.M.

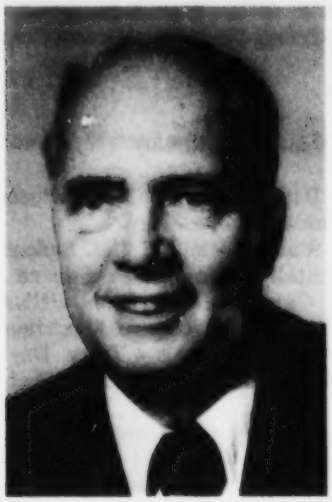
12:00 - **Lunch With Speaker** (Salon 3)
- **Colorado Oxygenated Fuels Program** - Tony Massaro, Director, Environmental Affairs, City of Denver, Colorado

2:00 - **Session 6 - Technical** (Manitoba Room)

Co-Chairmen - Doug Hayes, Chief, Bioenergy Research and Development, Bioenergy Division, Energy, Mines and Resources Canada, Ottawa, Canada
- Hadi Husain, Wardrop Engineering, Winnipeg, Manitoba
- **Distillation and Separation Techniques** - Hadi Husain, Wardrop Engineering, Winnipeg, Manitoba
- **Enzymatic Hydrolysis** - Brian Foody, President, Iogen, Ottawa, Canada
- **Acid Hydrolysis** - Per Assarsson, St. Lawrence Reactor, Mississauga, Ontario
- **Recent Developments in Fermentation of Grain and Wood Sugars** - Morris Wayman, Morris Wayman Ltd., Toronto, Ontario
- ***Zymomonas* - A Superior Process Organism For Motor Fuel Alcohol Production** - Hugh Lawford, Consultant, Bio-Hol Developments, Toronto, Ontario

4:00 - **Closing Remarks** - Ted Speers, Biomass Energy Institute

E.A.(Ted) Speers, P.Eng.
Chairman of CANPAC '88 Conference



Chairman, Board of Directors, Biomass Energy Institute
President, INRAD Industrial Research and Development Ltd.
Speers McGonigal (1980) Ltd., plastic fabrications

The breadth of technical work encompassed by Ted Speers activities is illustrated by the following:
-Quality control in copper casting, extrusion and drawing;
-Application of vacuum distillation to mercury recovery from amalgam and to freeze drying techniques;
-Design of equipment and application of herbicides, fungicides, weedicides and fumigation of cargo ships, warehouses, and boxcars;
-Application of scintillometers, liquid and plastic phosphors to radiation work and atomic installations;
-Knock rating tests on gasolines for a provincial government;
-Set up Petroleum Laboratory, Chemical Engineering, UBC;
-Electronic instrumentation, including automation controls.
Ted Speers graduated from the University of Manitoba with a B.A. and took a chemical engineering degree at the University of Briish Columbia.

Ted is past-president of the Association of Professional Engineers of Manitoba.

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Otto Lang, Chairman Session 1

Mr. Lang became chairman of the Transport Institute at the University of Manitoba in August, 1988.

Mr. Lang was called to the Bar in Saskatchewan in 1956, and later, in 1972, to the Bars of Ontario, the N.W.T. and the Yukon. In 1988 he was admitted to the Manitoba Bar. He joined the faculty of Law at the Unviersity of Saskatchewan in 1956 and became Dean and Professor of Law there in 1961.

In 1968, Mr.Lang was elected M.P. for Saskatoon Humboldt and joined the cabinet. Over the next eleven years he was acting Minister of Energy, Minister of Manpower and Immigration, Minister of Justice and Attorney General of Canada, Minister of Transport , and Minister responsible for the Canadian Wheat Board. After the 1979 election he joined James Richardson & Sons, Limited in Winnipeg, as Executive Vice-President of Pioneer Grain Company. and remained there until early in 1988.

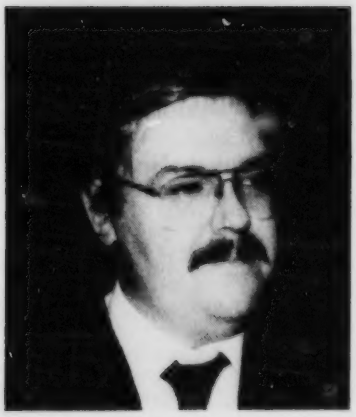
Dr. Tony Taylor, Energy, Mines and Resources Canada, Ottawa, Ontario.

Director general of Transportation, Energy Branch, Energy, Mines and Resources Canada.

Tony graduated from Queen's University, Kingston, Ontario and the University of Toronto. He received his Ph.D. from the Massachusetts Institute of Technology, Cambridge, Mass. Dr. Taylor has taught courses at several Canadian Universities and before joining the Federal government eleven years ago was a consultant. Tony Taylor is responsible for the coordination of the alternative fuels program.

Michelle Heath, Research Advisor, Canadian Energy Research Institute, Calgary, Alberta.

Michelle joined CERI in January, 1988 as a Research Advisor. From 1981 to 1985, Michelle was Planning Analyst with Husky Oil Operations Ltd. and was responsible for preparation of economic and financial analysis of investment opportunities. In this capacity, Ms.Heath developed modelling systems using the Interactive Financial Planning System, as well as developing an operational production forecasting system. She is a graduate from the University of Calgary.



Allan Jenkins, P.Eng., Manager, Renewable and Alternative Energy, Manitoba Energy and Mines.

Allan is involved with technical analysis and policy formulation on alternative fuels produced and used in the Province of Manitoba. Prior to joining the province, he conducted research at the University of Toronto into thermal processing and biochemical engineering, including the production of ethanol. Mr. Jenkins has Masters and Bachelors degrees in Applied Science Chemical Engineering from Toronto.

NOTES FOR SPEECH TO THE
1988 CANADIAN POWER ALCOHOL CONFERENCE

by

MR. TONY TAYLOR
ENERGY MINES AND RESOURCES CANADA
OTTAWA, ONTARIO

FEDERAL POLICY ON ALCOHOL FUELS

Good Morning Ladies and Gentlemen.

You will not be surprised to hear that we at Energy, Mines and Resources are quite often asked if there is a federal policy on alcohol fuels, and if so what it is. I will try to provide an answer to the question, knowing how important it is to many of you, especially the proponents - and perhaps opponents - of alcohol-gasoline blends.

Is there a federal policy on alcohol fuels, and for that matter on alternative fuels in general? The short answer is yes. The longer answer is of course less straightforward. Before I elaborate, let me offer a view of what policy is.

Policy could be said to define a state that an individual, an organization or in our case a government has realized, or wishes to realize. For example, Canada has a clear policy of encouraging regional equity. One of the tools used to try to realize this policy is transfer payments to selected provinces. A more immediate example perhaps is support for developing the Hibernia oilfield, which apart from its energy implications is intended to improve the economy of Newfoundland.

It is worth distinguishing between policy, objectives and goals. Policy, as I have noted, in my mind is concerned with a desired state. Objectives, on the other hand, are tangible achievements that are essential elements in attaining that state. The USA in the early sixties announced the objective of putting a man on the moon. That was not a policy; I believe the policy that the man on the moon helped establish was that the USA reaffirm its technological superiority over the rest of the world, especially of course over the USSR. We need not debate whether or not the policy was fulfilled; it certainly achieved its objective. As for a goal, that is an intermediate step on the way to an objective. One of the goals in the US program to put a man on the moon was to send an unmanned rocket round the moon. This was an essential step in achieving the stated objectives and policy, but was not an end in itself.

Objectives and goals are articulated more clearly than is policy, and often objectives are directed at more than one area of policy. In other words, the outside observer - and sometimes the bureaucrat too - must sometimes interpret policy from the announced goals, objectives and programs of government.

How does this relate to federal energy policy respecting alternative fuels? First, it is important to recognize that the Government of Canada has put in place a number of measures, and made a number of announcements, that together constitute a strong statement of intent with respect to alternative fuels. The policy of the Government of Canada is to encourage greater diversity of energy use in Canada, especially in the transportation sector.

Diversity means using less conventional oil, and making greater use of our assured domestic resources. What are the measures that are the manifestation of this policy? There are several. All the ministers of EMR in the last decade or so have stated the importance they see in replacing oil-based fuels. Most recently, Minister Masse in his statements on his new energy efficiency and diversity initiative has emphasized the need to develop alternative energy sources.

A major initiative in the government's policy on alternative fuels dates back, in fact, to the mid-1970's. When the excise tax on gasoline was introduced, it was specifically directed at oil-based fuels. An important aspect of the tax - apart from the government's apparently endless need to raise revenues - was to discourage use of oil, and by implication to encourage use of alternative fuels.

EMR has launched two major programs to encourage alternative fuels. From 1980 to 1985 we provided grants to fund the conversion of vehicles to propane. We had a clear objective in that program, which was to establish a self-sustaining propane vehicle industry. The goal was to increase the number of propane vehicles on the road in Canada to 120,000, a number we judged would be sufficient to launch a self-sustaining auto-propane industry. We met this goal, and we believe the objective was realized too. The propane industry in Canada continues to grow without conversion grants from government. It does, however, continue to receive substantial support, not only through the excise tax exemption described above, but also through ongoing assistance to the marketing efforts by the propane gas association of Canada, and through federal funding of research to ensure propane technology remains competitive with gasoline technology. Several provinces, notably Ontario, also provide substantial support to propane.

In 1982 EMR launched the natural gas for vehicles (NGV) program, which provided grants to help develop both a fueling station network and to encourage conversion of vehicles. Our objective for NGV was also to establish a self-sustaining industry in Canada, but we recognized that this objective would be more difficult for natural gas than for propane. There were several reasons for this difficulty: The technology for NGV in 1983 was less developed than for propane; the vehicle conversion costs for NGV were - and remain - substantially greater than for propane; and unlike propane, there was no established delivery network for compressed natural gas. Our program goals were accordingly more modest than for the propane program. We had a goal of 35,000 vehicles and 120 fueling stations by 1987. We met the station goal, but fell short of the vehicle goal. As a result, we have continued the vehicle conversion grants, and will regularly reevaluate this program to see what else we should and can do to achieve our objective.

I would like to change gears a little now, and talk about some of the criteria we use in determining the objectives that together help realize our policy of diversifying transportation energy. Bear in mind of course that objectives often respond to more than one area of policy. The most important criterion, as far as EMR is concerned, is that any alternative fuel encouraged by government must have the clear potential to be economically competitive with conventional fuels. There are many qualifications to this. We recognize, for example, that alternative fuels face horrendous market entry barriers, because of the massive investments made in the established gasoline and diesel infrastructure. We believe it is reasonable to give government support to overcome such barriers.

We also recognise that many alternative fuels are potentially better from an environmental viewpoint than are conventional fuels. It is difficult to quantify the value of these environmental benefits, but clearly society should favour the use of environmentally more benign fuels. Environmental reasons can therefore justify government support to alternative fuels. Similarly, other government policies, such as regional development, can provide valid arguments for support to alternative fuels. Nonetheless, an essential prerequisite to EMR's recommending assistance to the commercial use of an alternative fuel is that the future commercial viability of the fuel be very clear.

Another important criterion - in a way more critical than economic viability - is that the alternative fuel be technologically acceptable. The new fuel must perform safely and reliably. If we believe that a potential alternative fuel is promising, but that the technology is not ready, we have provided research, development and demonstration funds. We have, for example, provided substantial funding to the demonstration of methanol, as a fuel for large engines. I am sure most of you here have heard of our mile program, which funds several trucks and buses powered by methanol. We have also supported field trials of alcohol-gasoline blends, to establish the performance of different levels of blends in Canada.

How does all this relate to the topic of key interest here today, energy policy with respect to alcohol-gasoline blends? First, given what I believe is a strong policy of support in principle to alternative fuels, my colleagues and I have a mandate to assess the role that alcohol blends could play in Canada. As you probably know, we have invested a lot of time and money in these assessments. In particular, we published last year a comprehensive discussion paper on oxygenated gasolines, a discussion paper that treated as comprehensively as we could the energy, economic, technical and other issues that surround the use of these fuels. Several conclusions emerged from our studies and the subsequent discussions with other government departments, other governments, the private sector and consumer groups.

1. Alcohol blends could displace significant quantities of oil, and contribute to diversifying transportation energy.

2. Alcohol blends could provide important benefits to the natural gas industry, in the case of methanol, and to the agricultural and forest industries, in the case of ethanol.

3. Technically, blends have no major drawbacks for the majority of vehicles, although there is still considerable controversy in this area.

4. Environmentally, blends have some advantages and disadvantages, and on balance environmental factors neither encourage nor discourage their use.

5. Economically, blends might be able to compete in some circumstances with gasoline, but in most cases, blends cannot compete at present.

Does this last point mean that the federal government will not adopt the objective of assisting with the development of an alcohol blends industry? Not necessarily. Although we do not believe alcohol blends are clearly competitive with gasoline - there are other factors that must be weighed. A major one of course is the potential benefit to agriculture of providing additional markets, through the fermentation of cereals to fuel ethanol. Another is the regional development benefits that local production of ethanol could bring. A third is the benefit to the methanol industry of a larger - much larger - domestic market. Unfortunately, weighing these factors and reaching a consensus is not easy. Many of you know that we have been discussing for some time - perhaps too long - what support if any it would be appropriate to offer to alcohol fuels. Many different interests are involved, and the government has not yet reached any conclusions on what should be done.

It is worth discussing what the alcohol proponents have asked the Government of Canada to give in the way of support to alcohol blends. There have been two major elements of the requests for support: Accelerated phaseout of leaded gasoline; and relief from one or both of the federal sales and excise tax. In particular, the rationale for relief from excise tax is that other alternative fuels - including neat alcohols - are exempt at present from this tax.

We now have accelerated phasedown of leaded gasoline. Environment Canada now expects that use of leaded gasoline will effectively cease by the end of 1990. Phasedown was not brought forward specifically to help alcohol blends, of course, but one major aspect of the support requested has been met.

Neither alcohol blends, nor the alcohol component of such blends, are exempt from Excise or Sales Tax. There have of course been many discussions of the benefits of exempting these fuels from tax, but one reason they are not is the potential conflict such exemption would have with present tax policy. The recent white paper on tax reform makes a strong argument that, for reasons of fiscal responsibility and accountability, revenue generation should be considered as distinct from revenue collection. One can argue that there are many exceptions to this rule, including the present exemption of natural gas and propane from the Excise Tax. On the other hand, one can also argue that principles are meant to be followed, no matter how many exceptions there may already be. In effect, finance officials might argue that two wrongs don't make a right.

There is also a difficulty with the current Excise Tax Act, when considering alcohol blends. The act specifies that the tax applies to

gasoline and substantially similar fuels. Because blends are meant to be used in place of gasoline in vehicles designed for gasoline, it is difficult to argue that they are not substantially similar. Exempting alcohol blends from excise tax might require amending the Excise Tax Act, which would not be lightly undertaken.

Another thorny problem concerns butane, but not in this case because of its effect on volatility. If we argue that alcohols as non-oil products should be exempt from the Excise Tax - and I believe the argument has some merit - then should butane co-produced with natural gas also be exempt when blended with gasoline? Imagine the nightmare that would raise for tax enforcers, given that part of the butane now blended with gasoline is a byproduct of oil refining.

These complexities are a major reason why no clear objective to encourage alcohol blends has yet emerged from the Government of Canada.

In conclusion, I regret that I cannot be more encouraging with respect to the prospects for government support to alcohol blends as part of energy policy. There is a government policy on alternative fuels, including alcohols; it is to encourage their use as a means to diversify the mix of energy used in Canada's transportation system. The steps used in promoting this policy include assessing the technological and commercial viability of all likely alternatives to gasoline, and to provide support to help develop technology if needed. For those fuels that would be economic once in the market place, or that would bring other substantial benefits to Canada, the government can and has set objectives for market penetration of those fuels, and where appropriate has provided financial support. As yet, it is not clear that alcohol blends meet the criteria for such market entry support.

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FUTURE CANADIAN DEVELOPMENT

BY

MICHELLE HEATH

Canadian Energy Research Institute

A PRESENTATION FOR
CANPAC '88

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Ontario Minister of Energy • Saskatchewan Energy and Mines

FUTURE CANADIAN DEVELOPMENT

Good morning ladies and gentlemen. I would like to begin by thanking Beth Candlesh of the Biomass Energy Institute for inviting me to speak at this conference. I recognize myself as the junior member speaking amongst my peers. In preparing a study for the Canadian Energy Research Institute on ethanol and methanol as alternative transportation fuels in Canada, I have had the privilege of discussing "alcohol fuels" with a great many of the speakers you will be hearing from over the next two days.

The transportation sector is almost totally dependent on petroleum. Petroleum resources are finite. They are being steadily depleted while at the same time being subject to increasing demand. It is this knowledge which today suggests the potential for building upgraders, expanding frontier resources and developing alternative transportation fuels.

THE EFFECT OF CHANGING CRUDE OIL PRICES ON THE MARKET FOR ALTERNATIVE TRANSPORTATION FUELS

There are a number of catalysts that effect the market for alternative transportation fuels. Oil price is one of them. As early as the 1920s, "gasohol", (a gasoline and ethanol mixture) was popular in the United States as a farm fuel, but that was before petroleum-based gasoline became readily available. Since gasoline could be produced cheaper than the alcohol fuels, they were forgotten as fuel sources until the dramatic price increases of the 1970s. Once again the question of alcohols as alternate fuel sources

became of interest to the consumer; could they realistically extend the petroleum fuels, or even replace them?

A collapse in world oil prices would render untenable any investments made or contemplated in the use of alternative fuels. When crude prices are low or on the downturn, as in 1986 when Saudi Arabia tried to recapture its market share by offering to undercut the prevailing oil prices, alternate fuels become a topic to set on the back burner until the next oil price crisis. However, when crude prices increase, there is a renewed interest in more secure fuel sources and the potential for alternate fuels once again becomes a viable topic.

It is a topic only, though, because historical developments have indicated a down side to high crude prices in the development of alternative transportation fuels. In June 1975, when the Petroleum Administration Act adopted what has been termed the "high price scenario" for oil and gas production and natural gas prices were tied to those for crude oil at Toronto, prices escalated.

At the time the high price scenario (which saw prices reaching $27 U.S. per barrel in the 1990s) was initiated, it was thought that it might stimulate the emergence of new energy alternatives. This did not happen, however. Investors have not been anxious to become involved in a situation where a lower cost commodity--crude oil--is replaced by a higher cost one with greater uncertainties attached--alternate fuels. Because our energy sector has been largely supported by private sector investors whose main objective is profitability, the development of alcohol fuels has not been sparked. Decline in crude prices have been met by government intervention through various incentives designed to bolster the prices paid to the

producers of non-renewables, thus further deterring private sector participation in renewable alternatives.

I would like to emphasize it is crude price "shocks" and the emerging public and political will for cleaner burning fuels, more than depleting oil reserves, which will affect the question of the viability of developing alternative transportation fuels.

ENVIRONMENTAL CONCERNS AND REGULATORY CHANGES THAT WILL AFFECT THE TRANSPORTATION FUEL REQUIREMENTS

(Slide 1)

Environmental concerns are currently becoming a hot issue in Canada. A noted highlight presented in the Energy Options report released by Marcel Masse this past August stated, "Environmental goals should be accorded the same importance as other economic and social goals in the planning, development and use of energy." The federal government announced in 1986 that by the end of 1992, tetraethyl lead must be phased out of our gasoline. However, on September 13th of this year, Environment Minister Tom McMillan advanced the deadline for the elimination of lead from gasoline to December 1st, 1990. Mr. McMillan stated, "Health data provides compelling evidence that leaded gasoline should be eliminated sooner than originally planned." If tetraethyl lead is no longer used as an octane enhancer in gasoline, other octane sources will have to be found. Canadian refiners, being forced to make changes to their operations to compensate for the loss of octane in their product, have two main options to match fuel octane to engine compression ratios:

(i) more severe refining of petroleum fuels, converting low octane hydrocarbon molecules into differently structured but chemically similar molecules with higher octane values by reformation, alkylation and isomerization (PACE, 1985); and

(ii) the addition of high octane chemicals such as oxygenates or aromatics (benzene, toluene and xylene).

In considering these options, the refiner will have to consider the economics, the marketability of the product, and the effect on the existing fleet of vehicles, as well as the environmental impacts of such changes.

In other words, ladies and gentlemen, although petroleum-based fuels will remain Canada's principal transportation energy source in the foreseeable future, there are several valid reasons for considering a transition towards ethanol and/or methanol as alternative fuels in the immediate future:

(Slide 2)

- declining conventional light crude oil reserves;
- unstable crude oil prices;
- acknowledged government efforts to eliminate lead from Canadian fuels for health, safety and environmental reasons, forcing refiners to establish alternate octane sources;
- the "greenhouse effect" and ozone concerns;
- declining diesel fuel quality; and
- poor grain prices, suggesting the need for agricultural diversification projects.

In spite of the fact that the energy security issue does not tend to have the impact on the plausibility of alternative transportation fuels that price shocks, environmental concerns or the necessity to develop diversification projects have, one must recognize that it took over a decade for

unleaded fuel use to reach 50 percent of market penetration, even though the vehicle fleet turned over in that period of time and CGSB Standards preferred it to regular gasoline. It would seem reasonable, therefore, to assume that even under favourable market conditions, it would take at least 5 to 10 years or longer to switch even a limited portion of this petroleum-based market over to an alternative fuel source.

According to Transport Canada, 68 percent of Canada's total petroleum consumption is absorbed by the transportation sector. Eighty percent of this is attributed to the road mode, of which two-thirds is consumed by private passenger automobiles. My point being that, if Canadians, in particular vehicle users, face a future whereby conventional crude sources will be in short supply, and if it is true that by the year 2000, half of the world's oil will be produced in the Mid-East, an area recognized for instability and therefore a potentially insecure supply source, then efforts to start an immediate transition to other alternative fuel sources should be initiated.

Over the next two days, I'm sure you will be hearing from the experts about how ethanol and methanol are produced as well as their characteristics as relatively efficient, clean burning fuel sources. Their performance and compatibility with current vehicles and the fuel distribution system will also be discussed, so perhaps I will move directly into a brief discussion of what is currently happening in the methanol fuel market and then onto the economic prospects of the ethanol fuel industry.

METHANOL

INTRODUCTION

Canada is one of the largest producers of methanol in the world and has enjoyed a reasonably assured export market for the excess production. Until recently, however, Canadian producers were competing in a surplus world market. In 1986, the total capacity of the world's methanol plants was 26.5 billion litres. This exceeded the world demand by 6.25 billion litres.

(Slide 3)

The expansion in worldwide capacity that occurred in the 1970s created an uncertain market situation for Canadian producers. To aggravate the situation, new plants came on stream in third world countries which enjoyed the benefits of lower natural gas and labour costs as well as artificial exchange rates. The result was increased competition from the Middle East, Eastern Europe and Latin America which reduced the export markets for Canadian methanol manufacturers. Until the turn around about a year ago, Alberta Gas Chemicals Ltd., Celanese Canada Ltd. and Ocelot Industries Ltd., Canada's three world-scale methanol producers, were greatly in need of more diverse markets for their products. However, with the MTBE market expanding rapidly and a number of the third world Lurgi plants experiencing problems, Canada's methanol producers have managed to expand their markets.

Methanol as a "Neat" Alternate Fuel for Gasoline and/or Diesel Fuel

The automotive industry perceives methanol as the primary candidate for gasoline substitution. Increased requirements for light crude oil imports suggest a need for increasing the use of "neat" substitutes for the transportation industry. This, in turn, would lead to the widescale application of substitute fuels in personal vehicles.

The quality of diesel fuel is decreasing as the sulphur and aromatic content of these fuels increases. The U.S. Transportation Research Board found the cetane number for diesel fuel dropped four full points between 1972 and 1982, while according to the U.S. Motor Vehicle Manufacturers Association, the sulphur content rose from 0.19 to 0.31 percent between 1980 and 1983. Therefore, as not only the quantity but also the quality of Canada's crude supplies continue to deteriorate, precautionary measures must be undertaken to ensure environmentally safe upgrading of these fuels, or alternate fuel sources must be developed which can be used as effective substitutes.

Near-term substitution emphasis is being placed on methanol replacing road diesel applications, primarily in response to the introduction of tougher emission standards. Engine manufacturers in the U.S. are having considerable difficulty with current technology, designing engines which will meet the stringent diesel emissions standards set to be staged into effect in 1988, 1991 and 1994. As a result, methanol engines are becoming an attractive option for meeting the new standards, especially in overcoming the particulate problem. At least one methanol engine option will be offered for 1990/91 by a major engine manufacturer.

METHANOL: ENVIRONMENTAL IMPACTS

The acceptance level for carbon monoxide (CO) in Canada is 13 parts per million (ppm), whereas the United States restricts CO levels to 9 ppm. The reason for this difference lies perhaps in the fact that Canada has a large land mass and a relatively small population so, it is assumed, Canadians will not encounter the problems facing many of the major U.S. urban centres. The fact is, however, that a major portion of the population in Canada resides in urban areas, which should suggest taking a second look at the allowable carbon monoxide emission levels in Canadian cities.

In the United States, environmental considerations and public concern about carbon monoxide levels have reinforced the movement towards alternate fuels. California, in particular, is interested in substituting methanol for a good portion of their diesel fuels to lessen the polluting effects of this fuel. The methanol substitute is likely to be pipelined largely from Canada.

Both Colorado and Arizona have mandated the use of oxygenated fuels over the winter season. By requiring a minimum oxygen content of 1.5 percent by weight during January and February of this year, Colorado's Oxygenated Fuels Program resulted in an 8 to 11 percent reduction in carbon monoxide levels. For instance, in downtown Denver the monitoring station registered a reduction of 9.36 percent. In future years, Colorado's program will be effective each November 1 through March 1 with a 2 percent minimum oxygen content requirement. If the United States feels the use of methanol may solve a portion of their pollution problems, perhaps Canadians should take a second look at the potential opportunities.

Another environmental concern emanating from fossil fuel combustion and currently under consideration in Canada is the "greenhouse effect" created when gases such as CO_2 and chlorofluorcarbons (CFC's) absorb some of the suns infrared rays, trapping them in the atmosphere and warming the earth. Scientists fear the long-term effects of this may seriously affect our way of living. Following the recent international conference on "The Changing Environment - Implications for Global Security", a Task Force on Energy and the Environment was estabilished to review the effects of CO_2 emissions in Canada.

METHANOL: ECONOMIC ASSESSMENT

The stability and future growth of the methanol industry in Canada may well be tied to the methanol producer's ability to promote the viability of methanol as a useful substitute for a portion of the current gasoline and diesel markets, as an octane enhancer for both fuels, and as a limiter of the polluting effects of diesel fuels.

By the mid-1990s, with lead phased out of our fuels, with flexible fuel vehicles attaining commercial production levels, with gasoline prices increasing, and with diesel quality continually decreasing, methanol may fare well as a gasoline and/or diesel substitute.

This relatively inexpensive, clean burning fuel, when used as a substitute for gasoline in dedicated or flexible fuel vehicles or when used as a replacement for diesel fuels, may not only provide the power lost through lead phase-out but may prove beneficial in meeting future air quality standards by decreasing the atmospheric NO_x and particulate levels. If California, described as the third largest consumer of petroleum products in

the world, has recognized the need to establish public policies aimed at encouraging methanol consumption for energy security and air quality purposes, perhaps Canadians should take note and consider using our methanol to prevent the aforementioned problem areas from reaching the proportions they have in other countries around the world.

ETHANOL

INTRODUCTION

Ethanol produced from biomass is a renewable energy source which offers immediate prospects for providing a premium liquid fuel from domestic resources as a partial substitute for conventional petroleum supplies. As an oxygenate with a high octane rating, it becomes a candidate for use as an octane enhancer in gasoline to replace tetraethyl lead. However, whether biomass-ethanol production will be socially, economically and environmentally justifiable is heavily dependent on a number of criteria, a few of which are:

(Slide 4)

- petroleum prices;
- the degree to which environmental concerns promote the use of oxygenated fuels to reduce the carbon monoxide and carbon dioxide pollution levels;
- the state of the agricultural industry, specifically,
  - the need for diverse markets;
  - grain prices, which determine the feedstock price for ethanol production;
  - production levels affected by climatic changes and consumer food demand; and
  - the demand for protein and animal feeds which determines the value of by-product credits attributed to the price of ethanol;
- whether ethanol is accepted as an octane enhancer and not only a gasoline extender; and
- the pace of ethanol fuel technology advancement and to what extent cost-effective production is developed.

Ethanol: Economic Assessment

As a renewable biomass fuel, opportunities exist to produce large quantities of ethanol for transportation. However, these opportunities are confronted with a number of economic costs. Whether the costs will outweigh the benefits is the question confronting Canadians.

There have been several reports published in Canada and a great many in the United States estimating production costs of ethanol from different sites, using various feedstocks and producing diverse volumes of alcohol. Many of the projects for which cost estimates are presented are still in the experimental stage and not yet commercially viable, as for instance that of producing ethanol from cellulosics. The point to be made is that each plant is unique in its feedstock characteristics, feedstock costs, operating parameters, plant capacity, by-products and even product quality. There are also unique financial obligations for each producer, such as the debt-equity ratio assumed, the interest rates to be paid, and the tax status of each company. Taking all these factors into consideration, it was necessary to consult with a number of producers in order to arrive at a fairly demonstrative set of production costs.

The Value of Ethanol

As a fuel extender, ethanol contains two-thirds the energy content of gasoline which ultimately results in reduced fuel efficiency. This suggests that the effective price of ethanol should be around two-thirds of the rack price of unleaded gasoline to be economically competitive on a mileage basis. However, with the octane value of ethanol being 30 percent higher than regular gasoline, ethanol's value as an octane enhancer would be

considerably greater than that of gasoline. If the value of the ethanol blends in the marketplace is to reflect the combined characteristics of a gasoline extender and an octane enhancer, its selling price, in relation to the rack price of unleaded gasoline, should currently range between $0.15 per litre and $0.50 per litre. As a neat fuel, the economic viability of ethanol is poor; however, as a gasohol or in an M5E3 blend, ethanol's value as an octane enhancer may, under certain assumptions, be a viable investment.

(Slide 5)

Another factor that affects the actual value of ethanol as a blended fuel is the volume of gasoline components (crude oil and butane) from the refinery which must be replaced if the same product slate and volatility specifications are to be maintained. As crude oil is more expensive than butane, the higher the crude backout from the gasoline pool, the better the economics of the blended fuel. However, the highly volatile nature of ethanol suggests that during the summer months, in order to maintain CGSB volatility standards, the base gasoline would have to be tailored in a manner which would suggest higher butane backouts and lower crude backouts, resulting in a more costly fuel.

An Empirical Assessment of the Ethanol Industry

I would now like to briefly discuss an empirical assessment of the economic outlook for an ethanol industry in Canada, based on data gathered from numerous public and confidential studies. The study prepared for the Canadian Energy Research Institute entitled "Towards a Commerical Future: Ethanol and Methanol as Alternative Transportation Fuels," analyzes four plant sizes (10, 50, 100 and 200 million litres per year

capacity), however, due to the time constraints I will mainly discuss the 10 and 100 million litre plants. It is important to note that promoting an ethanol industry as an agricultural diversification project would require plants no larger than the 10 million litre per year size, so that the animal feed by-product could be completely utilized in an integrated feedlot. However, to promote the use of ethanol as a fuel on a national basis requires larger commercial size facilities of the 50, 100 and 200 million litre per year size.

Financial Criteria

(Slide 6)

The financial criteria used to determine the viability of the project are:

- Rate of return on investment; and
- Payout or payback period.

Financial Evaluation

Financial evaluations were performed under a range of assumptions pertinent to an ethanol industry which enabled the examination of the impact of uncertainty on the economics of the projects.

(Slide 7)

The assumptions underlying the evaluation are provided in this slide. All four plants (10, 50, 100, 200 million litres per year capacity) have a start-up profile of 0 percent, 60 percent, 90 percent and 100 percent and a project life of 10 years. This time period was chosen simply because, as indicated by the actions of U.S. ethanol producers, if after 10 years the

project is not viable, the refinery will most likely be shut down. Construction of the refineries is assumed to take place in 1988.

Production Costs

The cost of ethanol production for fuel use in Canada will vary considerably, depending on the site and size of the plant. Large producers will have an inherent advantage in terms of their ability to more effectively market the fuel as well as realizing production cost savings related to economies of scale. The marketing of fuel ethanol may require both the influence and the financial resources of the large ethanol producers. There are circumstances, however, under which smaller plants can be viable and profitable, a good example of which is Mohawk's ethanol plant in Minnedosa, Manitoba. It is an ideal micro-model, where the plant provides local area farmers with a market for their grain production and, in turn, the local area farmers and residents provide the refinery with a market for both their ethanol fuel and the animal feed by-product.

The production costs for an ethanol plant can be scaled down by locating the plant near:

(Slide 8)

(i) the feedstock source, which may be:

- corn or cereal grain,
- fermentable wastes from a food processing or industrial facility, or
- pulp, if the technology can be developed to economically break the cellulose down to fermentable sugars;

(ii) a grain elevator for year-round storage and feed access;

(iii) a feedlot where the by-products can be fed directly to the cattle, saving drying, transporting and marketing costs; or

(iv) an oil and gas refinery, where the ethanol can be blended with gasoline.

(Slide 9)

Much of the controversy around the actual cost of ethanol production relates to its dependence on the variable costs of the feedstock used as well as the by-product prices. As can be seen in this slide, grain prices were on the decline for most of those 12 years. However, the drought of 1988 has resulted in an upward swing of grain prices.

(Slide 10)

Another pertinent factor which can vary both annually and regionally are the yields per acre from the diverse crops which Canada produces. The ethanol yield also varies by the type of crop.

Unit operating costs other than unit feedstock costs vary depending on plant size. The "estimated" unit operating costs net of depreciation, derived from both public and confidential data provided by ethanol producers, suggest that the remaining fixed plus variable operating costs for the four plant sizes should range as follows:

(Slide 11)

10 million litre/year plant: $0.23 - $0.28/litre

50 million litre/year plant: $0.20 - $0.25/litre

100 million litre/year plant: $0.18 - $0.23/litre

200 million litre/year plant: $0.17 - $0.22/litre

As indicated, unit operating costs for larger plants tend to be less than those for smaller plants because as noted earlier, the smaller plants do not have the advantages attributed to economies of scale.

(Slides 12)

As noted on this slide, only the 100 and 200 MM litres/year plants had positive rates of return. The larger plants appear to be more viable than the smaller plants. This exemplifies the benefits of economies of scale experienced by the larger plants, providing a savings of 5 to 6 cents per litre on the operating costs and 5 to 8 cents per litre on the capital investment in comparison with, for example, the 10 million litre per year plant.

Sensitivities

To investigate the effect of changes on key input variables on the economic returns to an ethanol producer, a number of sensitivity cases were performed on the base cases. However, time restrictions will only allow me to outline the results of a few of these sensitivities.

The Significance of Shifts
In Feedstock Prices

(See Slide 13)

Shifts in feedstock prices can definitely enhance or reduce the value of a project. Shifting the feedstock costs from $110 per tonne to $85 per tonne, for example, increased the value of the 10 million litre per year optimistic case from where it did not reach payout after 10 years of production to where it does payout in 1998. In the 100 million litre per year plant, this downward shift in grain price resulted in an increase in rate of return of 10 percentage points in the optimistic case. In addition, the plant

pays out 2 years earlier. On the other hand, raising the feedstock prices by $30 per tonne, to $145, completely eliminates the rate of return on the optimistic case.

A decrease in feedstock prices of $25 per tonne can increase the value of the projects by as much as 10 percent; whereas, raising the price by $30 per tonne results in all the projects remaining non-viable over 10 years. A sensitivity performed on these same cases, extending the project life to 2008, suggests that over a longer period of time, reducing the value of the feedstock by $25 per tonne, would prove to be most beneficial to the smaller, 10 million litre per year plant.

The Value of Animal Feed
By-Product to an
Ethanol Project

(Slide 14)

Crediting back the revenue from the distilled dried grains by-product to the ethanol project is extremely significant to the economics of an ethanol plant. Although raising the selling price of the DDG by $50 per tonne to $220 per tonne is not enough to bring even the optimistic 10 million litre per year plant on-stream, a $50 per tonne increase in the DDG price increases the value of the 100 million litre per year optimistic case from 4 percent to 11 percent and advances the payout period by 2 years (1996-1994).

(Slides 15, 16)

These results underline the importance of maintaining assured prices and markets for this animal feed, if an ethanol industry is to achieve and maintain commercial viability. The effects of varying both DDG and

feedstock prices to attain specific rates of return on each of the base cases can be determined from the following two slides.

The Value of Government Subsidies
Versus Government Grants To An
Ethanol Industry

Technological advancements in the near future may well see the financial viability of an ethanol industry become positive. However, as indicated above, current technology does not provide the necessary economics. At today's costs of ethanol production, its usefulness as an "economically" viable fuel source or an "economic" substitute for tetraethyl lead does not appear sound. However, lead phaseout and increasing public pressure to minimize any detrimental effects on the environment from fossil fuel combustion suggests there may well be a role for alcohol fuels in Canada. The need for regional diversification projects may also lend credence to this issue. As illustrated however, government support would be a necessity to provide adequate funding to place this fuel competitively on an equal footing with other fuel sources. Fuel tax exemptions will not be adequate to support the 10 million litre agricultural diversification projects let alone that of a large scale commercial project. This suggests that if ethanol is to be produced as a fuel source, government grants and/or subsidies may be required.

(Slides 17, 18, 19,)

The next two slides illustrate the value of government capital and/or subsidies on the base cases presented in this report. They illustrate the value of the government subsidy required to offset various levels of capital investment to achieve specific rates of return. (NOTE: Slide 19) In

this table, the cost to the government of providing a capital grant of 50 percent of the total project capital requirement is compared to the level of subsidy that would allow the plant to achieve the same rate of return.

(Slides 20, 21,)

Keeping the benefit to the plant constant, these next two slides suggest that for plants demanding assured rates of return of less than approximately 8 percent, the cost to the government would be less if investment in the project was maintained through subsidies. However, if the required rate of return is higher, the cost to the government by 1998 would be less through capital grants necessary to maintain these rates of return, as opposed to applying subsidies to the project.

Of these two promotional incentives, capital investment or "upfront" money may be the only method capable of promoting interested developers to participate in an ethanol industry. The risk of subsidies being reduced or even removed reduces and inhibits the confidence level among the interested parties.

Provincial Incentives

(Slide 22)

At the moment, there is no federal incentive program for ethanol fuels. However, a number of provinces do provide support for oxygenated fuels:

- British Columbia has proposed an effective rebate of $0.20 per litre on the provincial road tax for the ethanol portion of a gasohol blend if an ethanol project begins operating in B.C.
- Alberta offers a $0.05 per litre tax rebate on the oxygenate portion of motor fuels.

- Saskatchewan provides a $0.04 per litre grant for a 10 percent ethanol blend; however, if the distributor is marketing a blend of less than 10 percent ethanol, a grant is paid in proportion to the amount of ethanol in the blend (i.e., if the blend contains 3 percent ethanol, the incentive is 1.2 cents per litre on the blend).

  The incentive will be guaranteed to the distributor for each contract the distributor has with a producer. The guarantee period is 4 years and begins when the distributor first takes delivery of the ethanol from a producer. A participant in the Ethanol Production and Marketing Incentive Program also relinquishes participation in any additional provincial government support program such as the Venture Capital Program or SEDCO.

- Manitoba offers a $0.25 per litre rebate on ethanol produced from biomass and sold as gasohol.

- Ontario offers a full tax rebate on its $0.093 per litre road tax for the alcohol portion of a blended fuel.

Ethanol: Conclusions

In the long term, the marketplace will determine the ultimate value of ethanol to Canada. However, in the short-term, investments must be initiated to determine the potential merits of the industry by promoting any accessible technological development which might reduce the production costs associated with this industry.

A successful ethanol industry will require the close alliance of the agricultural industry (grain farmers and feedlot managers), the alcohol producers, the oil refiners, the distributors, the vehicle manufacturers, both federal and provincial governments, the marketer and ultimately the consumer. Ethanol production and distribution will have to be just one part of a fully integrated system in order to minimize the risks associated with the development of a new industry and, at the same time, maximize the returns.

To fully examine the risks and opportunities that would accompany the institution of alcohol fuels across Canada, further research

and development spending will be required. To prevent excessive outlays of public and government funds, developing a commerical size plant involving all the stakeholders and determining with as minimal funding as possible the viability of ethanol as a fuel for Canadians may in the long term prove less costly than funding numerous research projects across Canada. To suggest the answer should be taken from a financial spreadsheet may prove naive, if future environmental concerns culminate in the need for oxygenated gasolines.

(Slide 23)

This slide is a map which suggests six sites in Canada which may be ideally situated for the development of an integrated ethanol facility, based on their proximity to an oil refinery, a feedstock source, a large enough beef population to support a feedlot using the animal feed by-product and an assured retail market for distribution to the motor fuel users. Though in all likelihood there are other viable locations in Canada which could support a plant of between 50 and 100 million litres per year capacity, the sites selected were Montreal, Quebec; Oakville, Ontario; Regina, Saskatchewan; Edmonton and Balzac, Alberta; and Taylor, British Columbia. The refinery names on the map are suggestions only as to the players who might be approached in becoming involved in this commercial experiment.

The farmers in the given regions could experiment with feedstocks and research the development of a grain high in starch and low in protein, with high tonnage yields per acre that could be dedicated solely to ethanol production. At the same time, the refiners could experiment with tailoring their product to meet CGSB standards and the distributors could test different methods of transporting alcohol fuels. Researchers involved in the

development of the enzyme necessary to convert cellulose to glucose could be hired to take part in developing an alcohol fuel industry for Canada. The flexible fuel automobile manufacturers must also be involved in such a way that the fuel developed will enhance the value of their cars to the consumer, with government fleet vehicles being used for testing purposes.

(Slide 24)

If the ethanol industry is joint-ventured with an oil refinery and a feedlot for a specified time period, and if enough capital is invested to assure each participant a fair rate of return during the experimental stages, methods may be determined to lower production costs as well as solve many of the existing problems associated with an ethanol industry. In all fairness to previous investments made, the established pioneers in this industry should be invited as participants in such an experiment. The time has come to step from the empirical, experimental stage to the practical and determine if both economically and environmentally, there is a commercial future in Canada for ethanol as an alternative transportation fuel.

Ladies and gentlemen, thank you for your time and consideration.

MANITOBA'S EXPERIENCE WITH ALCOHOL FUELS

Allan Jenkins, P.Eng.
Manitoba Energy and Mines

I understand that Manitoba has been chosen as the site for this CANPAC conference in recognition of the lead the province has played in the development of a Canadian ethanol fuel industry. For those who are new to CANPAC, and those who have forgotten what happened over the seven years since the last CANPAC, I will provide a brief overview of Manitoba's experience, from the government perspective.

Manitoba first publicly indicated its support for alcohol fuels with the introduction of a tax exemption for gasohol in the May 1980 provincial budget. Prior to this a good deal of consultation and deliberation was involved in arriving at the decision to provide a road tax subsidy, however, there was nowhere near the hesitancy we have seen in other provinces.

There were two significant reasons for Manitoba's motivation. First, the exemption was established at the peak of the oil crisis, when the National Energy Policy was blooming. Security of supply, a strong national issue, was also a policy within the borders of most provinces. Manitoba saw the exemption as an inducement to the development of significant in-province production of a renewable, sustainable alternative fuel that would in time prove less expensive than gasoline. At the time it was anticipated that the road tax exemption would only be a short term necessity, to cover start-up and production cost differentials until gasoline exceeded ethanol in cost, as predicted by various economic forecasts. Donald Skagen, the President of Mohawk Oil publicly suggested at the time that a sunset of three to four years would be appropriate and Manitoba agreed that this was a sufficiently long time.

The other, more significant reason for Manitoba's action was the opportunity for regional development, a traditional government priority, that was offered by Mohawk Oil's proposal to convert an inactive potable alcohol distillery in Minnedosa to fuel ethanol production. The local economy would be strengthened by providing increased employment, a market for local grains, a source for animal feed, and a renewed tax base for the Town of Minnedosa.

The Mohawk proposal was particularly attractive to Manitoba. The company did not ask for direct government involvement - no capital subsidy, loans or loan guarantees. Any project that requires both capitalization and ongoing subsidy from governments raises serious doubts. The risk of investor capital demonstrated Mohawk's commitment and belief in the viability of this alternative fuel project and encouraged government decision makers.

Another major attraction in Mohawk's case was that the company had a marketer for their ethanol - themselves; their integration certainly was an advantage. If there is a major flaw that can be singled out in other fuel ethanol plant proposals submitted to Manitoba it is that the proponents show no guarantee of a marketer (or market) for their production, such a letters of intent or contracts.

In May 1980 the foreseeable market for alcohol fuel was 10% ethanol in gasoline blend (gasohol) and our consultants' reports indicated that such a fuel, delivered by responsible marketers, performed at least as good and possibly better than gasoline in existing vehicle stock. The exemption was incorporated into The Gasoline Tax Act to specifically allow for gasohol. The revised Act has continued since then to allow exemption only for ethanol containing not more than 1% water, derived from biomass materials, manufactured in Canada, denatured, and in a concentration not less than 10% in gasoline.

Following the provision of the exemption, Mohawk refurbished the Minnedosa distillery and began production in 1981, with an annual capacity of 5.5 million litres of anhydrous fuel ethanol per year. This was the first and remains the only biomass based fuel alcohol plant in Canada. Mohawk will be discussing their plant (now 8.5 million litres per year capacity) and experience with alcohol fuels in other presentations to be given at this conference.

The level of gasohol tax exemption has varied up and down over the years. In May 1980 it was set equal to the full amount of the gasoline tax which was 4 cents per litre. However in the early 80's the gasoline tax was ad valorem, based on a retail price averaging formula. By the time that Mohawk was producing in the fall of 1981 the exemption had risen to 5.7¢ a litre, and subsequently it rose to 6.4¢ a litre in the spring of 1982.

As the original intention was to phase out the exemption over three to four years (although the intention was public knowledge no sunset clause was included in the Act) it was necessary to alter the method of fixing the exemption value. In 1982, in consultation with Mohawk the exemption was fixed back at 4 cents per litre with the understanding that the exemption would be phased down until the alcohol content only was exempt, that is, on a pro-rated basis, equal to 10% of the gasoline tax. Subsequent reductions therefore occurred, to 3 cents per litre in June 1983 and 2.5 cents per litre in June, 1984. The tax exemption has remained at 2.5 cents per litre since then because, as you are all aware, gasoline costs did not continue to rise nor did the the costs of ethanol production and marketing fall to meet gasoline costs.

There is no intention at this time to alter the exemption level from 2.5 cents per litre. We calculate this as suitably near to what companies would require to bring industry average ethanol production costs in line with gasoline costs. In addition, we anticipate that other forms of subsidization are or will become available to producers from other levels of government. Manitoba understands that an ongoing subsidy continues to be

necessary to make fuel alcohol production from grains viable, particularly at the small scale of production at Minnedosa. Manitoba's viewpoint is that our gasohol tax exemption should foremost be set at a level that produces at least a neutral economic balance in the province. While cumulatively Manitoba is still behind in cost/benefit, at the present levels of sales and production we see a balance becoming positive. We also undertstand that production of ethanol for export would, if necessary, require a different type of subsidy, as obviously the road tax exemption applies only to fuel sold in the province. Proponents of this type of operation should expect to provide a very well developed business plan with a cost/benefit analysis for the province before final consideration would be given.

Annual sales of gasohol in Manitoba have risen to a level ranging up to 65 million litres of gasohol a year. This represents slightly less than 5% of Manitoba's gasoline market. The annual cost to Manitoba in foregone tax revenue averages $1.5 million. This is balanced by direct and indirect employment created at Minnedosa and elsewhere in Manitoba, by taxes paid by Mohawk and by financial advantages that accrue to the agricultural community. Mohawk provides a market for distressed grains, and a means to improve cash flow for local farmers. The distillers dried grain byproduct is sold to local feedlot operators, displacing higher cost imported soybean meal.

Presently Mohawk is the only marketer of alcohol fuels in the province, selling untailored blends of 10% ethanol in leaded, unleaded and high octane unleaded gasolines at equivalent cost to comparable gasoline products. Consumer acceptance of gasohol has been very good, and the government is not aware of any problems with the use of this fuel. The public perceives the 10% ethanol blend as a quality product, due in some part to successful marketing of ethanol's octane boosting and antifreeze properties. Mohawk Oil has benefitted with both increased market share and goodwill in this province.

The Manitoba government's experience with gasohol reflects this general concensus. Together with Energy Mines and Resources Canada, Manitoba Energy and Mines supported a controlled fleet test of gasohol fuel from 1981 to 1983. Ethanol was bulk blended to a 10% level in untailored Esso 2000 unleaded gasoline using straight Esso 2000 as the control fuel. The fleet consisted of 25 tests and 25 control vehicles ranging from subcompacts to pick-ups and large panel trucks belonging to the Manitoba Telephone System. In addition to the fleet runs, various other tests were carried out including controlled route driving cycles and simulated-driving chassis dynamometer and engine dynamometer tests. The results were very encouraging. No differences in driveability or other operating problems were apparent in either the fleet or driving cycle tests. While fleet fuel consumption was not significantly different (on a volume basis - on an energy basis gasohol was more efficient), chassis dynamometer tests indicated that gasohol was 1.7% more efficient, and the engine dynanometer

showed that gasohol achieved 7% greater power at 10% better efficiency. While the test report concluded that a savings of 1 to 2% could be achieved through the use of gasohol (attributed to the leaning effect of the oxygenate) consumers are generally advised by Manitoba Energy and Mines that equivalent mileage should be expected.

Routine engine maintenance requirements for vehicles operated on gasoline or gasohol were the same and there was no evidence that ethanol in the gasohol caused any deterioration of fuel system components. Disassembly and inspection, at test completion, of two types of engines operated on gasohol and two similar engines operated on gasoline, indicated no differences in engine wear on either set of engines.

Methanol blended fuel has also been made available to the public in Manitoba. From 1982 to 1985 a blend of 5% methanol/2% isobutanol/93% gasoline, supplied by Canadian Methanol Canadien, was sold through Domo retail outlets in Winnipeg. Winnipeg - headquartered Canadian Methanol Canadien was an early developer of methanol fuel.

From 1983 to 1986 Manitoba Energy and Mines and Energy, Mines and Resources Canada also supported fleet tests of low and high concentration methanol blends. Manitoba Telephone System vehicles were again involved in the low blend test, as well as various vehicles supplied by member companies of the Motor Vehicle Manufacturers Association. Initially the low blend consisted of 5% methanol and 2% isobutanol cosolvent in 93% untailored regular unleaded gasoline. In August of 1984 the test fuel was changed to conform to the proposed Canadian General Standards Board (CGSB) blend of 4.75% methanol, 4.75% isobutanol and 90.5% regular unleaded gasoline. The gasoline blend stock was tailored with anti-fouling and anti-oxidant agents, with butane concentrations seasonally adjusted to give a similar distillation curve and Reid Vapour pressure as the control gasoline.

The results of the low blend methanol test were not nearly as encouraging as the previous gasohol tests. Various driveability problems were encountered with the methanol blend fuel vehicles, including hesitation, reduced power, stalling, engine knock, and overall poor perceived performance. By the end of the tests most of these problems were resolved through adjustments to the tailoring of the blend stock, however, hesitation and a general dissatisfaction with the methanol-fueled vehicles was not eliminated.

Fuel consumption, which was significantly greater than gasoline with the untailored blend, improved when tailoring was introduced and continued to improve as researchers learned to tailor to ambient conditions.

Manitoba has, at various times considered further amendments to The Gasoline Tax Act, to allow exemption for methanol and to allow pro-rating of the gasohol exemption for other concentrations of ethanol, such as would occur with a 5% methanol 3% ethanol blend as sold in other areas of Canada.

These considerations were eventually rejected for several reasons:

i) Driveability and engine wear problems observed in our fleet tests together with reports of similar observations in U.S. tests and vehicle manufacturers' cautions led Manitoa to conclude that methanol blends were not sufficiently developed at the time to provide retail consumers with a reasonable equivalent to gasoline for use in existing vehicle stock.

ii) Fleet tests demonstrated that tailored blend stock was necessary to avoid a number of problems with methanol use. As Manitoba has no refineries, only pipeline terminals, the logistics for sourcing tailored blendstock in Manitoba are unfavourable.

iii) Methanol was found during our tests to require stricter control of transport, storage and blending than ethanol.

iv) Manitoba was concerned that possible negative consumer reaction to methanol blends would spill over and affect gasohol sales, which had proven by all of Manitoba's experience to be a trouble-free equivalent to gasoline. For example some methanol blends were being marketed as "gasohol" and the government had received some complaints about misfueling and driveability with these particular blends.

v) Manitoba was anticipating the development of federal fuel quality standards for methanol blends.

vi) Methanol was lower cost than gasoline at the time of consideration. Subsidy was considered unnecessary as blend costs were determined to be equal or lower than gasoline in most cases.

vii) Use of methanol, which is not produced in Manitoba, would provide relatively little economic benefit to the province. While methanol from biomass was promoted as a developing technology for Manitoba, this was seen as being very long term based on natural gas reserves available in Alberta.

Given these reasons Manitoba determined that incentives for commercial retailing of methanol blends were inappropriate at the time. On the other hand, no disincentives were brought forward, as Manitoba saw that industry was progressing to improve the product.

High blend fleet tests of methanol were mentioned earlier. These also were carried out from 1982 to 1986 with Manitoba Telephone System fleet vehicles both converted on the after market and factory built by Ford to run on neat methanol. Volkswagen and Toyota also provided factory built vehicles that were operated independently of the MTS fleet. These tests were started with a 90% methanol/10% unleaded gasoline blend, but in the final phases the compositon was adjusted to 85% methanol/15% hydrocarbons, using gasoline and butane as the hydrocarbons, seasonally adjusted to improve dirveability.

Similar to the low blend tests, the researchers went through a learning curve as blend fuel consumption improved from a very excessive level until it became comparable to gasoline on an energy basis. Cold weather driveability, and excessive engine wear remained as problems throughout the test. A general conclusion was that more development of methanol fuel systems and engines was required before commercialization would be advisable.

Subsequent to these tests, Energy, Mines and Resources Canada has been sponsoring an ongoing test in Winnipeg of transit buses with diesel engines converted to run on 85% methanol, under the Methanol In Large Engines program.

In addition to providing the incentive for sales of ethanol blended fuel, Manitoba has supported a number of research studies of lower cost alternative feedstocks for ethanol production.

Manitoba Energy and Mines was involved in an early consultative role with Canertech, a federal crown corporation, when the company was developing plans for a wood-to-ethanol conversion process. Canertech's work eventually culminated in pilot plant research into hydrogen fluoride acid hydrolysis of cellulosics, carried out in Winnipeg by Wardrop Engineering Inc. and funded entirely by Energy, Mines and Resources Canada.

Manitoba Energy and Mines, together with Energy, Mines and Resources Canada and Mohawk Oil jointly sponsored a study of the feasibility of applying the Iotech enzymatic cellulose-to-ethanol process at Minnedosa. Manitoba was impressed by a projected 30 cents litre (1986) cost of ethanol, and by the advances made in enzymatic conversion of cellulose. However, Manitoba considered that the timing for integration of the Iotech process was premature, a main reason being that low ethanol prices were dependent on the sale of lignin byproduct as an offset, at values for which a suitable market was not guaranteed. Brian Foody of Iogen will be discussing enzymatic hydrolysis later in the conference; I understand that further significant advances have been made since our feasibility study was completed.

Last year Manitoba Energy and Mines and Energy, Mines and Resources, together with Carnation Foods Ltd., sponsored a study of feasibility of fuel or food/industrial grade ethanol production from potato processing wastes. The study indicated that fuel ethanol could be produced at a price of 30 cents per litre (1986, with after tax IRR 25 - 35%) at Carnation Foods Carberry Manitoba plant. I understand that Carnation Foods is interested in commercializing with an appropriate partner to produce the ethanol.

Prior to closing I would like to recognize the work of the various advocates, researchers and companies who provided impetus to the high degree of activity in alcohol fuels in this province. The Biomass Energy Institute Inc., and the researchers of the now disbanded fuels group at the Industrial Technology Centre in Winnipeg, are two groups I have not already mentioned who I would single out for fostering knowledge and development of alcohol fuels in Manitoba.

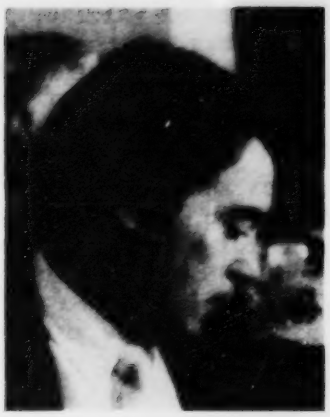
Manitoba continues to see benefits in the production and use of alcohol fuels, particularly ethanol. We also see that this has remained an infant industry for a number of reasons, some within and some beyond your control. Manitoba hopes that progress will occur here at CANPAC '88 and will continue so that by the time the next CANPAC is called you will be well on your way to strength and viability.

Ewen Coxworth, Chairman Session 2

Manager, Biomass Resources Program, Saskatchewan Research Council. Saskatoon, Saskatchewan.

Ewen graduated with a Ph.D. in Organic Chemistry from the University of California,Berkley, in 1959, following undergraduate education at the University of Saskatchewan. After graduation, his first employment was with Uniroyal Research Laboratory in Guelph, Ontario.

In 1961, Dr. Coxworth went to the Saskatchewan Research Council in Saskatoon. Ewen served as a technical advisor to research and development projects in Bangladesh, Sri Lanka, and Ethiopia from 1976-82. Areas of major interest to Dr.Coxworth have included the improvement of feeding value of crop residues for feed; handling, compaction and use of straw as fuel; enzymatic hydrolysis and fermentation of forages and crop residues to produce liquid fuels, industrial feedstocks and animal feeds. Ewen is a Director of the Biomass Energy Institute.



Don O'Connor,P.Eng. General Manager, Alcohol Fuels Division, Mohawk Oil Co. Ltd., Burnaby, BC.

After graduation with a degree in Mechanical Engineering from the University of British Columbia in 1973, Don worked for B.H.Levelton & Associates Ltd until 1981. At that time, Don O'Connor joined RDC Research, Development & Consulting Ltd., and was involved with investigating alternate fuel opportunities for Mohawk. In 1985, Don became General Manager of the Alcohol Fuels Division for Mohawk Oil Co. Ltd. Don is vice-chairman of the Canadian Renewable Fuels Association.

Del Shafer, Director, Agri-Industry Division of Technology Distributors International Ltd. Saskatoon, Saskatchewan.

Del has spent the last two years reviewing and developing the integrated plant philosophy on behalf of clients in Saskatchewan. This most recent activity tops off more than twenty years in Canada's resource and petrochemical industries.

Andrew J. Daugulis, Associate Professor of Chemical Engineering at Queen's University, Kingston, Ontario.

Andy earned his M.Sc. from the University of Western Ontario, and his doctorate from Queen's. His research activities involve the design and characterization of bioreactors used in microbial and animal cell culture for the production of enzymes and bioactive polypeptides. Recent work has also focussed on the integration of reaction and product recovery in biological processing, notably in the production of ethanol by extractive fermentation.

SEVEN YEARS OF EXPERIENCE AT MOHAWK'S MINNEDOSA ETHANOL PLANT

PREPARED FOR:

CANPAC '88

WINNIPEG, MANITOBA

BY

DON O'CONNOR, P. ENG

MANAGER

SUPPLY & MANUFACTURING, FUELS

MOHAWK OIL CO. LTD.

INTRODUCTION

Seven years ago this month Mohawk Oil Co. Ltd. began operations at its ethanol facility in Minnedosa Manitoba. It was a time of great interest in ethanol throughout Canada and the United States. The memory of gas lines and energy shortages were still fresh in everyone's mind. There were a lot of experts in the field of ethanol production and use and there were proponents and opponents of fuel ethanol.

Today plant across North America put out 30-40% more ethanol from a given configuration than the experts thought possible in 1981. In North America consumers have accumulated over 3/4 trillion miles with ethanol gasoline blends, thats the distance to the sun and back 4,000 times and we still have experts, proponents and opponents of fuel ethanol.

From our experiences at Minnedosa we have been able to reach two conclusions:

1. You can't predict the future by only looking at the past.

2. People will always find a better way of doing things than the way they are doing it today.

Lets review some of our experiences at Minnedosa to see how we reached these conclusions.

THE ORIGINAL CONFIGURATION AND FEEDSTOCKS

In 1980 it was determined that feed barley was the lowest cost source of starch available for a plant situated in Manitoba. The plant was designed to produce 5.3 million litres a year using barley. After several months of operation it was determined that although barley was the lowest cost source of starch it wasn't the feedstock to use if you wanted to make the lowest cost ethanol.

Other factors such as the fibre and protein contents of the grain are equally important in determining the best feedstock. You must be able to process the grain and high fibre grain such as barley requires different pumps than grains such as corn. In 1981 there was little interest in the value of distillers dried grain as a protein supplement. I'll talk more about that later.

The second feedstock to be used was corn. The plant, originally being a whiskey facility, had been designed to use corn. Corn was substantially more expensive than barley but we had an immediate improvement in plant operating rate, maintenance costs dropped and ethanol production costs dropped. The DDG also became easier to sell. We found that #4 & 5 corn worked as well or better than #2 and cost a lot less. To ease the cost of corn we found that 20% barley could be run without a significant change in plant operations. We also had DDG customers tell us that as long as there was 51% corn in the feedstock they didn't care about the barley, but they didn't want rye in it. Looking back that statement should have made us ask a lot of questions about the DDG and the way it was being used and sold, but it was several years before we learned the true significance of what we were being told.

By now we are up to 1984 and our plant has a capacity of about 6.7 to 7.0 million litres a year. Production costs have dropped every year and plant output has increased every year. We keep reaching plateau's in plant operation were we don't think we can do any better, may be a 1/10 of a cent a litre here or there but conditions keep changing, grain prices drop and then when they go up something else happens and production costs stay the same or continue to drop.

One year there is a lot of rain at harvest time and there was a lot of sprouted rye available. We start using it at 5% and find that there is no change in the palatability of the DDG and we don't need as much alpha amylase. Eventually we use 10% with 80% corn and 10% barley and have a low cost feed stock with substantial savings in enzyme costs.

The sprouted rye didn't last forever and neither did the corn. The amount of corn produced in Manitoba dropped year after year throughout the early 1980's. Importing corn from the U.S. was obviously not the answer as it did little for the local economy. Feed wheats looked attractive, the starch and fibre content were about the same as the 80/20 blend of corn and barley and there was plenty grown in the local area.

The switch was made slowly by increasing the amount of wheat in the mash bill until 100% wheat was being used. The plant output was maintained at the same level as corn. There were several changes that were noticed with the switch. The first is that corrosion rates of mild steel tanks dropped. The mash and stillage were less acidic than when corn was being used. This change in pH was also noticed in the beerstill. The soluble protein in the mash was precipitating under certain temperature and pH conditions and causing more frequent clean-ups of the beerstill. This has been controlled to an acceptable level through the use of enzymes and chemicals. More frequent cleaning of the fermentors has also been required with the use of wheat.

The use of wheat rather than corn results in DDG with 34-35% protein rather than 28% level with corn DDG. This results in a more valuable protein supplement.

THE PRESENT CONFIGURATION

Last fall we went through a de-bottlenecking process at the plant and combined with the addition of 2 new fermentors we were able to increase capacity by 20% to 8.4 million litres. All of this was done at a cost of about $75,000.00.

Some of the things that were done include rotating the feeder to the hammermill by 90°. This resulted in a more uniform feedrate and the effective capacity of the system was increased by over 30%. A simple solution but one that is typical in processing industries when plants routinely run in excess of rated capacity.

The capacity of the beerstill reboiler was increased by laying it on its side rather than standing it vertically. The piping arrangement also provided less restriction in this orientation. The only drawback was that it stuck a couple of feet out the side of the building.

In the early days the reboiler on the beerstill required frequent cleaning due to fouling. Three consultants had suggested solutions ranging from exotic low NPSH pumps to digging pits to install the existing pumps. The solution that worked for years was to find the correct orifice to create enough back pressure in the system to prevent flashing in the reboiler. When more capacity was

required last year the whole still was lifted 5 ft by removing a redundant hi-wine section from the top of the still that was left over from the whiskey days and replacing it with a spacer at the bottom of the column. This simple solution provided the increase in capacity that we were looking for.

The other major mechanical problem that we solved with an innovative solution was the use of a plate heat exchanger for the mash cooler. The original spiral exchanger developed a leak which resulted in contaminated cooling water. The location of the leak was on a weld and it could not be guaranteed that a repair would be successful. The cost of a new exchanger was about $110,000. I had seen a plate exchanger operating at a plant in Austria where it was working successfully when potatoes were being processed. A similar unit for our application cost just over $20,000 and it has worked very well for us in spite of what the experts told us. It has had the extra advantage of being expandable so when we increased capacity last year it was a simple task of adding further plates to increase its cooling ability.

THE CO-PRODUCT - DDG

A little over a year ago we began to look at the benefits of integration of an ethanol plant with the rest of the agricultural community both forwards into a feedlot meat packing operation and backwards into the grain farms. The study showed significant advantages for various types of integrated operations. The benefits could add up to a total saving of 30¢/L over existing production costs. We have not yet progressed with any of the integration possibilities because one of the things that struck us was that very few of our DDG customers were aware of the research that has gone on over the past 5 or 6 years concerning the feeding of DDG.

Over the past six months we have been providing our customers with some of the research results and visiting as many of them as we can. We are concentrating on the dairy industry because this group can probably afford to pay more for DDG than other groups. Dairy cows require a high level of by-pass protein in their diet. Non by-pass protein is degraded in the stomach where it does little good. By-pass protein is hard to come by. One researcher at the University of Alberta has been trying to increase the by-pass protein of canola meal through cooking and acid treatments. He believes that one reason for the higher productivity of the American dairy industry is their better access to processed protein supplements.

DDG has a by-pass protein level of about 50% of the total protein content. Soybean meal for example has a by-pass protein level of 25% of the total protein content. Looking at the potential value of DDG to dairy producer in comparison to the soybean meal has is currently using we find;

Soybean meal
- $400/t
- 45% total protein
- 25% by-pass
- $3555/t by-pass protein.

DDG (Wheat)
- 35% total protein
- 50% by-pass
- At $300/t - $1715/t by-pass protein.
- or at $3555/t by-pass protein the producer can afford to pay $622/t.

The extra value to the dairy producer that we have not yet captured at the plant works out to 31¢/L of ethanol.

We are making some progress with the dairy producers. We are selling DDG in bags at the same price as soybean meal and we are concentrating the marketing of this to farmers with cream quotas. By-pass protein is also important to other animal groups.

One of the interesting things is that if DDG can be sold for $600/t then the plant has a negative feedstock cost and is immune to changes in wheat or corn price changes. In fact the plants may make more money when feedstock prices are high. This is quite a change from 1981 when plants recovered only 35% of their feedstock costs through the sale of DDG.

The various statements that people made over the years such as "as long as it has 51% corn then the DDG is o.k." were symptomatic of a lack of understanding of the qualities of DDG, why it worked, or how it should be used. It isn't going to be easy to make the change overnight on how the feed industry measures protein, but it is a change that has started to happen and it will only bring benefits to industries that produce high by-pass protein feeds.

CONCULSIONS

I hope that these examples of our experience at Minnedosa have shown you how we reached our conculsions of:

1. You can't predict the future by looking at the past.

2. People always find a better way of doing things.

THE INTEGRATION OF ETHANOL PRODUCTION WITH CATTLE FEEDING

Most of you are familiar with the primary product of an ethanol plant or distillery, but not all of you are familiar with the other products of these facilities and their economic importance, in particular the distillers grains by-product.

My presentation has to deal with the economic benefits of integrating a fuel ethanol production facility with other agri-business processes and in particular the integration with a beef cattle feeding operation. It is my intention to share with you the results of the past two years of our research into this subject and to provide you with some food for thought.

Technology Distributors International Ltd. combines the various skills and disciplines needed to use new products and processes in agri-business projects, including integrated ethanol plant/feedlot projects.

The government of the Province of Saskatchewan has provided assistance to our clients to examine the potentials of integration and to develop a data-base which can be used for the further development of the industry.

The development of a reliable data base is a key factor in the growth of the industry. Much of the published information, gathered from various sources which have differing points of view, is often misleading.

As much as we'd like to take credit for developing the concept of an integrated ethanol process/feedlot - we cannot. It is not a new idea. The practice of integrating distilleries and livestock goes back to the small farm still on the prairies. On a larger and more recent scale the fuel ethanol producers of the '70's in the U.S. were forced to look at alternate ways of maintaining their profitability as the perceived energy crunch dissipated. The concept of feeding livestock and, in particular beef cattle, caught on and spread throughout the States. The integrated producers vary considerably in size from the small 1 million gallons per year family run operation to the larger units of Archer Daniels Midland and Simplot.

As we attempted to learn more about this industry and its transferability we encountered two major informational problems.

1. The larger apparently successful producers who kept records and conducted feeding trials were not interested in sharing this data. The fact that they continued to expand and the packing houses paid a premium for their beef suggest they were on to a good thing.

2. The smaller independent producers were very willing to share any information they had. The problem was most of these producers did not have documentation to prove feed rates, rates of gain and other significant data points. Although we could see their facility and evaluate the technical process of the ethanol plant it was difficult to determine the impact in the feedlots. We were then left to review the published works of the universities and to extrapolate this data to Western Canadian feedlot conditions. The extrapolated data was then reviewed with our contacts who were operating facilities. As a result we have taken a very conservative approach in our economics and in our feeding recommendations. It will be very important for the industry to conduct in-depth well documented feed trials in a commercial feedlot setting in the very near future in order to develop optimized diets with their high probability of very significant cost benefits.

The Canadian feeding industry has had some experience with feeding distillers by-products as well but not in the integrated sense. The experience has ranged from the home still variety to the larger enclosed feedlots in Ontario feeding 35% dry matter (DM) material as a protein supplement. In all the Canadian cases we find the farmers and feedlot operators like the by-products but because they do not obtain the full benefit they are prepared to purchase them at a disposal value price only. This situation is not entirely the farmers' fault as most commercial distilleries are not prepared to spend time and effort on optimising this product and providing it on a consistent basis day-in and day-out.

Wet Distillers By-products for Growing Ruminants

Results show that wet distillers grains (WDG) are an excellent protein source for the growing ruminant. In two steer growth trials and one lamb growth trial WDG feed showed superior results in gain, feed efficiency and protein efficiency compared to soybean meal (SBM). Averaged over the three growth trials WDG was 2.14 times greater in protein efficiency than SBM. WDG showed some advantage in growth performance over distillers dried grain (DDG). Other research has shown DDG to have about twice the protein efficiency values of SBM. Calcium hydroxide or ammonium hydroxide ensiled WDG and exclusion of air will allow an ensiling process that would not otherwise occur and increases the storage time considerably.

All rations containing distillers grains resulted in weight gains greater than animals fed urea and greater than or equal to those fed SBM. In another trial steers fed dried distillers grains and solubles (DDGS) gained 7% faster on 4% less feed than those on a conventional ration.

Many researchers have conducted feeding trials which suggest that distillers feeds may contain an unidentified factor which increases urea utilization in ruminant rations.

The results suggest that processing procedures may influence nutritional properties. Although drying procedures vary, DDG is usually dried in a single process while DDGS is made by adding condensed distillers solubles (CDS) to DDG and then drying a second time. It is quite possible that the second drying could destroy whatever was enhancing the urea utilization.

The University of Minnesota fed groups of steers thin stillage instead of water and posted excellent gains. The steers which were fed the thin stillage gained an average of 3.55 lbs. per day in contrast to the control group at 3.48 lbs. per day. The rations fed were balanced to meet the animals' full protein and energy requirements. In addition to the improved rate of gain, researchers noted the thin stillage steers consumed 1.44 lbs. of dry matter less and required 78 lbs. less feed per 100 lbs. of gain than steers drinking water.

Condensed distillers solubles are high in crude protein and phosphorous and have considerable potential for use in liquid supplements for cattle.

Research suggests that including 8.5% CDS in a urea based liquid supplement improves weight gain and feed efficiency when fed to finishing steers.

	Supplement	Supplement & Solubles
Average daily gain	2.48 lbs	2.85 lbs
Average intake	17.4 lbs	18.5 lbs
Feed/gain	7.0 lbs	6.5 lbs

To this point, the use of distillers feeds has been in the context of their use as protein supplements. Typically distillers feeds are dried and are thus too costly to use as an energy source. Research has been conducted in feeding larger volumes of distillers grains to livestock in order to determine their energy value as well.

Wet distillers grains of 40% dry matter and corn cobs were compared to corn silage and soybean meal. Both diets were formulated to contain 12% crude protein and 72% TDN. Steers fed the wet grains gained 0.26 lbs more per day on 11.6% less feed.

In today's feedlots putting 500 lbs on an animal at a conversion rate of 7.0 requires 3500 lbs of feed. The feeding of a WDG ration would provide free feed for every 10th animal, an attractive option to any bottom line.

Work by Farlin demonstrated a similar improvement when feeding WDG. At the 21% WDG level, feed intake, daily gain and fuel efficiencies were not different from the control fed cattle. At the 45% WDG level, feed intake was not affected but daily gains increased 10% and feed efficiencies increased 10.6%. When WDG replaced 75% of the corn grain in the diet, feed DM intakes were reduced 11% but gains were equal to the control diet and feed efficiencies increased 10% over the control.

Further evaluation work by J.L. Firkins et al supports the above data. The researchers suggest the improvement is due to a higher digestible energy than suggested by NRC or that the absence of starch in WDG may have resulted in a higher rumen pH and consequently fibre digestion may have been improved.

These studies would suggest that feeding WDG as a substitute for grain in finishing cattle at replacement levels up to 50% do not result in decreased animal performance and in fact, suggest better performance.

I mentioned earlier that WDG has a slightly better growth performance than DDG. Drying in small-scale plants is not economical unless an added value can be obtained from the product. Drying equipment represents a larger percentage of the capital cost of the project as the scale becomes smaller. Energy and labour requirements become greater and repair and maintenance costs become proportionately greater as well.

A common question asked by many interested in integrating a facility is "how many animals will I need to consume the by-product?". The answer depends on how you intend to prepare the by-product and the optimization of your process unit. Assuming we are talking about 800 lb steers and a 10 million litre per year ethanol plant, the following are the approximate herd levels required.

1)	Feeding whole stillage. The least cost, the least by-product revenue	3,000 animals
2)	Feeding WDG (40% dry matter) as energy and protein source (2/3 of ration). Moderate cost, by-product revenues at feed grain prices.	8,000 animals
3)	Feeding WDG (40% dry matter) as protein source only. Moderate cost, by-product revenues of protein prices (usually 3 x feed grain prices).	12,000 animals

As you can see there are several ways to dispose of the by-product or to optimize the process unit. For today's Canadian feedlot scene a combination of options 2 and 3 would be used with option 3 being the predominant option and option 2 being the fall-back position when cattle prices force a scaling down of feedlot capacity.

In summary, the amount of distillers feeds available for consumption in North America will increase several fold in the next few years. The production of dried distillers feeds will continue for some time, but as the drive for cost efficiency continues and the WDG feeding experience broadens, costs will force more and more of the product to be sold and consumed as wet distillers grains.

A considerable amount of research has been done to determine the feeding value of dry distillers feeds. However, much less is known about feeding the wet grains or stillage and it is in these areas where the need for research is the greatest.

There are significant differences in the feeding performance of WDG from different sources. For example, on a DM basis, barley feedstock may have a 33% protein content while WDG from HY320 feedstock could be as high as 45% or even 50%.

The efficient utilization of distillers grains in livestock and human food rations will become vitally important as we attempt to maximize the production of both food and fuel from cereal grains in the future.

The need to control all the variables in both the ethanol production process and the feedlot (for example, diet changes in the feedlot must be gradual and controlled) and considerations of process optimization present a powerful argument that at the present state of available knowledge, these economics can only be achieved in integrated facilities under common ownership and control.

ECONOMIC COMPARISON

One of the keys to long-term survival of an ethanol plant will be the ability to reduce costs and to obtain "real" value for its by-product streams. In our review process we have concluded the most beneficial integration is one of integrating with a feedlot. When I speak of integration, I do not mean just placing the facilities in close proximity to one another. The integrated facilities must share common ownership and control and be operated by facility managers whose role and rewards are based on optimization of the entire complex not individual profit centres. The integration process should yield the following benefits.

(1) Utilization of all by-product in an "as produced state". Removing the need for drying the high protein feed by-product as is conventionally done, reduces both capital and operating costs. Undried distillers grain has a significantly higher food value than when dried, and when fed in conjunction with the plant thin stillage stream as drinking water permits substantial improvements in feed conversion efficiency.

(2) The sharing between integrated components of specialized technical resources, experienced management personnel and labour reduces the overall labour cost.

(3) Reduction in overall capital costs due to common usage of water wells, sewage systems, offices, laboratories, machine shops, mobile equipment and feed preparation facilities.

(4) Elimination of transportation costs associated with marketing by-product.

In order to better explain the preceding benefits we should first look at each of the components as a stand-alone business venture.

Stand-Alone Ethanol Plant

A stand-alone ethanol plant would normally need to be in the order of 40 million litres per year in order to make economic sense. So that we can compare the integrated and non-integrated facilities we have estimated the construction costs of the 10 million litre facility.

1)	Grain storage, receiving and milling	$ 1,200,000
2)	Process unit and ethanol storage	4,700,000
3)	Utilities	2,000,000
4)	Buildings and infrastructure	1,600,000
5)	Stillage, drying, storage and shipping	1,400,000
6)	Indirect	1,100,000
		$12,000,000

The operating costs for a 10 million litre stand-alone facility could vary considerably, dependent on process technology, whether a new or refurbished facility and the control philosophy applied. We have assumed a new facility of a dual enzyme process with separate dry-house and moderate automation.

		Annual Cost
1)	Operating supplies	$ 750,000
2)	Feedstock 25,000 tonnes @ $100/tonne	2,500,000
3)	Labour (28 man years)	700,000
4)	Maintenance & overheads	1,000,000
5)	Utilities cost (including drying)	1,200,000
	Total operating costs	$6,150,000

In terms of revenue for the stand-alone ethanol plant we should have two sources. The ethanol product is assumed to be sold into the Saskatchewan marketplace where there is currently a subsidy and the product could therefore yield 55¢ per litre. The dried distillers grains are assumed to be marketed into the North American protein market where they could average $200/tonne.

1)	Ethanol Revenue	
	55¢/l x 10 million litres	$5,500,000
2)	DDGS Revenue	
	$200/tonne x 9000 tonnes	1,800,000
	Total Revenue	$7,300,000

The revenue at this level is capable of servicing the operating costs but even with a 40¢ a litre subsidy doesn't yield a major return on investment. One can understand why there is no rush to build stand-alone ethanol plants, even in Saskatchewan.

STAND-ALONE FEEDLOT

A modern "state of the art" feedlot constructed somewhere in the province of Saskatchewan is used as the basis for the following capital and operating cost summary. As in the case of the ethanol plant, costs are general and may vary somewhat due to location.

The capital cost of a 12,000 head feedlot will be in the order of four (4) million dollars comprising the following items.

1)	Feedlot - including land, landscaping, pens and fencing.	$1,800,000
2)	Feedmill - including grain storage, weigh scales	905,000
3)	Buildings - offices, machine shops, processing barns	670,000
4)	Utility Services - water wells, electricity	225,000
5)	Mobile Equipment - feed trucks, tractors, grader front end loaders	500,000
	Total	$4,100,000

The operating costs of that same unit would be in the order of $3,605,000 per year. It is assumed that a conventional silage/grains ration would be used as feed.

1)	Feed costs	$3,000,000
2)	Operating costs	260,000
3)	Salaries	345,000

1 General Manager
1 Office Manager
1 Foreman
1 Feedmill Manager
11 Full-time
2 Part-time

16 Man Years Employment

$3,605,000

The cost of cattle is not considered in this equation.

The revenues for a stand-alone feedlot of this size provide a gross income of $10 million. Subtract from this the cost of cattle purchased $6,000,000 and we are left with a net sales revenue of $4,000,000 to service operating costs, debt and interest. You can see the profit margins in the cattle feeding business are not high and cost reduction is of great significance to the cattle business as well. Provincial subsidies, rations fed, types of cattle fed and the seasonal nature of the calf crop all impact on the profitability of a feeding operation.

It has been recognized for some time that both the ethanol plant and feedlot operations benefit from the economics of scale up to an optimum point. These stand-alone optimum sizes are such that market entry is extremely difficult. Considerable study work has been undertaken to match size with market entry considerations, manageability, regional development impact and other similar factors.

The concept of an integrated facility that shares utilities, management and some services, reduces the less than optimum size penalties. Our conclusion has been that a smaller scale plant, with capacities of 10 million litres per year of fuel ethanol and 9,000 to 12,000 head feedlot capacity will match the above criteria and achieve appropriate economics. Careful attention must be applied to the design and incorporation of unique local advantages in the project concept.

When we place the two facilities in the same physical location you will notice several of the components are duplicated. Let us review some of those duplications.

1) **The Utilities Component** - The same water can be used for both facilities, similarly the sewage system, the electrical distribution, air compression, steam and other systems. Our analysis yields the following cost savings.

   $2,000,000 stand-alone ethanol + $225,000 stand-alone feedlot

   $2,025,000 = integrated cost

   $200,000 = cost savings of integrated site over stand-alone sites

2) **Buildings** - Only one of the office buildings is required. Maintenance facilities are also duplicated.

   $1,600,000 stand-alone ethanol + $670,000 stand-alone feedlot

   $1,900,000 = integrated cost $370,000 = cost savings

3) **Mobile Equipment** - The savings here is not as great as in the other areas but do have an impact.

   $75,000 stand-alone ethanol + $500,000 stand-alone feedlot

   $500,000 = integrated cost $75,000 cost savings

4) **Feedmills** - The central processing core is the feedmill, building, truck scales and conveying equipment are exactly the same for both needs, the only variable is the grain storage and the equipment capacities.

   $1,200,000 stand-alone ethanol + $905,000 stand-alone feedlot

   $1,270,000 = integrated cost $835,000 = cost savings

5) **By-Product Drying** - This equipment is not duplicated but as product is consumed from the production process, no dryer is required and no storage is required. A savings of $1,100,000 is projected.

In summary, the capital cost savings are:

1)	Utilities	$ 200,000
2)	Buildings	370,000
3)	Mobile Equipment	75,000
4)	Feedmills	835,000
5)	Drying	1,100,000
		$2,580,000

Using the summary as a guide we could then arrive at the cost of an integrated facility.

1.	Cost stand-alone ethanol plant of 10 million litres per year	$12,000,000
2.	Cost of stand-alone feedlot	4,000,000
		16,000,000
	Less cost savings	2,580,000
		13,420,000

However, our estimates of the costs of integrated facilities have been carried out on the basis of actual projects and accurate costing. Estimates for stand-alone facilities, on the other hand, have been taken from published information. When we estimate the cost of an integrated facility for our clients the grass roots numbers come out to between $12,500,000 and $13,400,000 depending on the land location and options.

An integrated facility as we said before has considerable savings in operating costs as well.

1)	Drying Eliminated: The cost of drying one tonne of DDGS is approximately $80	
	$80 x 9000 tonnes	$ 720,000
2)	Staffing Requirements: When the work force is combined (28 + 16 = 44) we create a number of redundant positions - managerial, maintenance, administrative, utility/ labour. An integrated facility requires 37 man years	
	44 - 37 = 7 man years saved @ $25,000/year	175,000
3)	Reduced utility costs due to reduced equipment and reduced operating supplies	110,000
	Total Operating Cost Savings	$1,005,000

We should now summarize all of the cost savings and/or improved revenues derived from the integration process.

1)	Capital Savings	$2,580,000	
	Over a 10 year project life this yields an annual savings of; (interest not being considered)		$ 258,000
2)	Operating Cost Savings		1,005,000
3)	Reduce feed consumption in the feedlot due to 11% improvement in fuel efficiency		
	3,000,000 x 11%		330,000
4)	Transportation to market cost savings on distillers grain - variable		
	Total Annual Savings (excluding transportation)		$1,585,000

Summary of Economic Comparisons

Stand-alone	(10 million litres) (12,000 head)	Integrated
12,000,000	CAPITAL	13,420,000
4,000,000		
16,000,000		
6,150,000	OPERATING	8,420,000
3,605,000		
9,755,000		
9,755,000	COSTS +	8,420,000
1,600,000	10% of Capital	1,342,000
		9,762,000
7,300,000	REVENUES	7,300,000
4,000,000		4,000,000
11,300,000		11,300,000
(55,000)	SURPLUS DEFICIT	1,538,000

To further examine the impact on our bottom line through integration let us look at the production costs of ethanol in ¢ per litre. It would be fair to say that a modern non-integrated facility of 10 million litres per year capacity could achieve an operating cost of approximately 43¢ per litre.

1)	Cost of production (by-product credit taken at source)	0.43¢
2)	Integrated Savings	
	A. Capital Cost Savings $258,000 - 10 million litres	02.6
	B. Operating Cost Savings $1,005,000 - 10 million litres	10.0
	C. Feed Savings 330,000 - 10 million litres	03.3
		15.9
	Cost of production possible in integrated facility =	27.1¢/l

If capable of producing at these costs the integrated facilities with even moderate improvements in technology and the oil price we will be able to compete at the wholesale rack price of gasoline.

Improvements in technology are coming from all quarters, high starch grains will reduce feedstock costs, better protein conversion through new cattle breeding techniques or aquaculture, high temperature tolerant enzymes and continuous saccharification and fermentation processes. All will help to improve efficiencies in the not to distant future.

CONCLUSION

TDI's research clearly demonstrates that moderately-sized integrated feedlot-fuel ethanol production facilities can produce, even at current commercially proven levels of technology, ethanol and finished cattle at substantially lower costs than larger stand-alone facilities.

Equally exciting is the potential for further significant cost reductions from technology already proven at the research level and ready for the process of commercial plant adaptation and usage.

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EXTRACTIVE FERMENTATION - INTEGRATED REACTION AND PRODUCT RECOVERY

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SUMMARY

Refinements have been made to a prototype process for the production of ethanol by extractive fermentation. The process is characterized by the *in situ* extraction of ethanol from a 7 L continuous stirred tank fermenter and the thermal recovery of ethanol from the extracting solvent, which is circulated in a closed loop through the process. Data are provided to show the efficacy and stability of the process under various operating conditions, and the near complete (> 96%) continuous conversion of a 300 g/L glucose feed.

INTRODUCTION

The productivity of conventional ethanol fermentations is limited because high ethanol concentrations in the fermentation broth decrease the ethanol production rate. This is a well known feature of many fermentation processes and is commonly referred to as end-product inhibition. Extractive product recovery is of particular interest in such cases since it may allow for the *in situ* removal of inhibitory product(s) by solvent extraction. In a Continuous Stirred Tank Fermenter (CSTF), the continuous contact between a water immiscible organic extractant and the aqueous fermentation broth will result in a lower and less inhibitory product concentration in the broth, thus keeping reaction rates high. In addition, such a process may (i) allow for the fermentation of more concentrated substrate feeds, and (ii) decrease product recovery costs (Maiorella *et al.*, 1984).

In work prior to this project, a computer model simulating the extractive fermentation of ethanol was derived (Kollerup and Daugulis, 1985a). It provided a convenient means of establishing a sensitivity analysis of the effect on the fermentation process of changing aqueous and solvent dilution rates, ethanol distribution coefficients and substrate feed concentrations. An extensive solvent screening program was then undertaken in order to screen over 1,400 solvents in terms of their predicted physical and chemical properties (Kollerup and Daugulis, 1985b), and based on the theoretical screening, 70 solvents were subsequently investigated experimentally. An operational prototype system was developed for extractive ethanol fermentation in a 1.3 L CSTF using a commercially available chemical, comprised largely of oleyl alcohol, as the extractive solvent (Kollerup and Daugulis, 1986; Kollerup and Daugulis, 1987). Operation of the prototype system obtained near complete (96%) conversion of a 535 g/L glucose feed and demonstrated the kinetic advantage of extractive fermentation. The

use of a number of other extraction solvents as well as various advantageous process features have been previously detailed (Kollerup and Daugulis, 1987c).

The present work describes results obtained from a 7.0 L CSTF system which has been designed using the results from the smaller scale. Besides scale, the major difference between the two systems is the inclusion of a flash vaporization unit in the current system to thermally recover ethanol from the solvent stream leaving the fermenter, thereby regenerating the solvent for repeated use. This unit replaces a packed bed water extraction column that had been used to strip ethanol from the solvent in the 1.3 L system (Kollerup and Daugulis, 1987).

MATERIALS AND METHODS

The composition of the medium for the initial batch phase of fermenter operation was: glucose, 150 g/L; yeast extract, 10.0 g/L; $(NH_4)_2SO_4$, 11.6 g/L; KH_2PO_4 , 2.7 g/L; $MgSO_4 7H_2O$, 0.75 g/L; pH adjusted to 4.0. During the continuous operation stages of fermentation, a 300 g/L glucose feed was used with the salts and yeast extract concentrations being increased proportionally from the above formulation. Medium sterilization of the 150 g/L medium was accomplished by autoclaving *in situ* for 30 minutes at 121°C . In the preparation of the 300 g/L glucose feeds autoclaving was not feasible due to the problem of caramelization of the glucose in the medium, which is exacerbated at high glucose concentrations, prolonged heat treatment, and high temperature. Therefore, instead of autoclaving, oxygen-free nitrogen was flushed through the concentrated media for 1/2 hour, and the head space in the medium reservoir was filled with nitrogen throughout the fermentation in order to minimize the occurrence of surface growth of aerobic contaminants. The yeast strain employed was *Saccharomyces cerevisiae* NCYC 716.

Ethanol concentrations were determined with a gas chromatograph equipped with a flame ionization detector and connected to a Hewlett-Packard 3390 A Integrator. Isobutanol was employed as an internal standard. D-glucose was measured at 640 nm with a colorimeter, using the dinitrosalicylic acid method (Miller, 1959). Cell dry weights were obtained by drying at 105°C to constant weight and cell viabilities were determined by a modified methylene blue staining procedure (Lee *et al.*, 1981).

SYSTEM OPERATION

Figure 1 presents a process flowsheet for the experimental extractive fermentation system; Tables 1 and 2 list the legend for the flowsheet and the flowsheet's components respectively. The fermenter (V_8) is a MBR laboratory chemostat with a working volume of 5.5 L. During system operation, the volume of the aqueous phase in the fermenter was 4.75 L. The solvent is introduced at the bottom of the fermenter through a ring sparger. Due to the difference in densities between the solvent and water, the former rises to form a second phase at the top of the fermenter; the volume of the solvent phase during operation was 0.75 L. The level of the interface between the two phases is set by the position of the inlet to the fermentation broth effluent pump (P_3). The degree of contact between the two phases can be independently controlled by a solvent recirculation loop; a pump (P_5) withdraws solvent from the top phase and returns it to the bottom of the fermenter.

An agitation rate of 150 rpm has been found to provide adequate mixing while maintaining a relatively stagnant solvent layer in the upper part of the fermenter, thereby allowing the withdrawal of primarily only solvent by the the overflow pump (P_7). The outlet of this pump is the feed to the staged separation column (V_9), which returns water and cells in this stream back to the fermenter. Filters ($V_{11} - V_{12}$) following the staged column serve to remove any remaining yeast cells before the ethanol-ladened solvent enters the flash unit. The flash

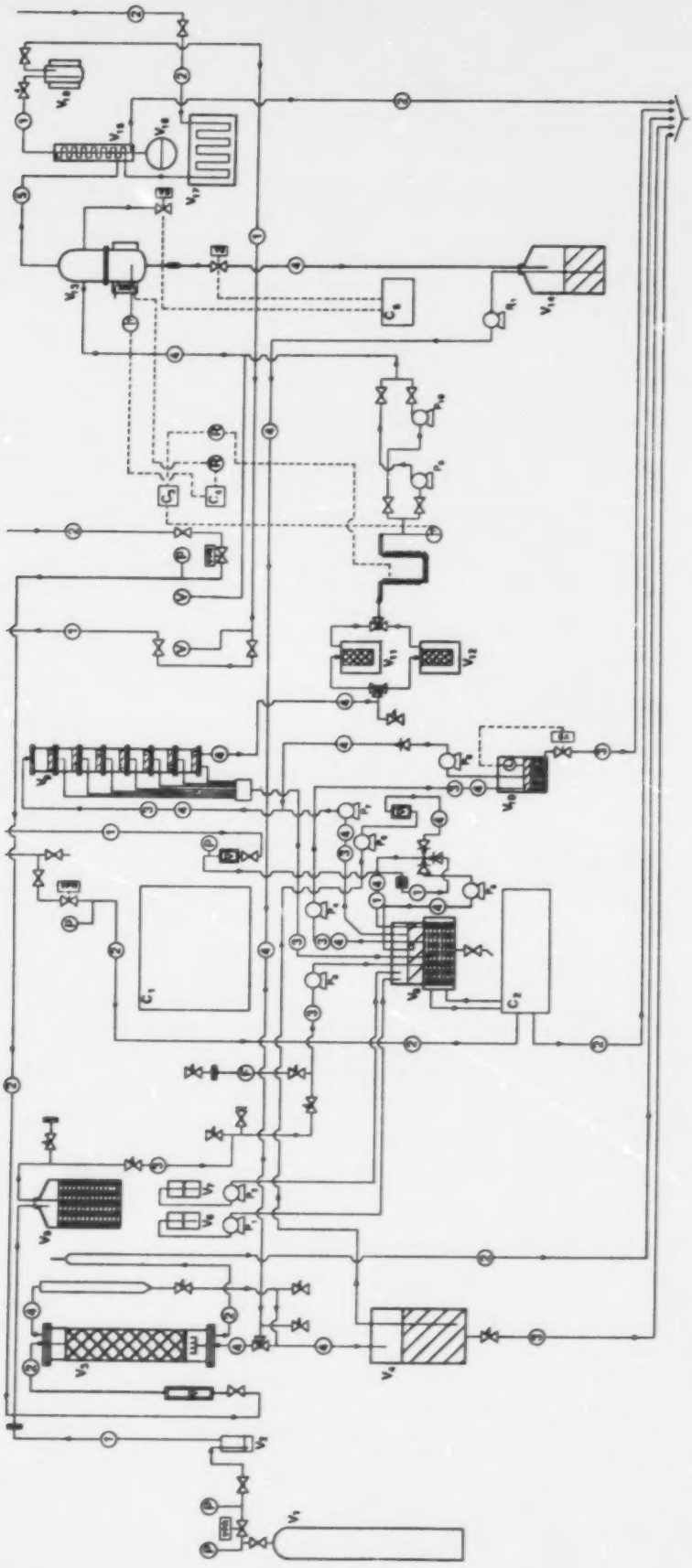

Figure 1: Process flowsheet for the extractive fermentation system.

Table 1: Flowsheet legend.

SYMBOLS:	
	VALVE
	PRESSURE REDUCING VALVE
	CHECK VALVE
	SOLENOID VALVE
	PRESSURE GAUGE (P)
	VACUUM GAUGE (V)
	THERMOCOUPLE (T)
	FLOWMETER (F)
	RHEOSTAT (R)
	LIQUID LEVEL SENSOR (L)
	ROTAMETER
	FILTER
	AQUEOUS VOLUME
	SOLVENT VOLUME

PHASE WITHIN TUBING:	
1	Air, Vacuum, N_2
2	Hot or Cold Water
3	Medium, Aqueous Fermentation Effluent
4	Solvent
5	Ethanol Vapour

Table 2: Flowsheet components.

VESSELS:	
V_1	O_2 - FREE NITROGEN CYLINDER
V_2	WATCH GLASS
V_3	SOLVENT REGENERATION COLUMN
V_4	SOLVENT RESERVOIR
V_5	MEDIUM RESERVOIR
$V_6 - V_7$	ACID - BASE RESERVOIRS
V_8	FERMENTER
V_9	STAGED SEPARATION COLUMN
V_{10}	FERMENTER EFFLUENT RESERVOIR
$V_{11} - V_{12}$	FILTER
V_{13}	VACUUM FLASH SEPARATOR
V_{14}	SOLVENT SURGE TANK
V_{15}	CONDENSER COLUMN
V_{16}	CONDENSATE FLASK
V_{17}	REFRIGERATED WATER BATH
V_{18}	VAPOUR TRAP

CONTROLLERS:	
C_1	FERMENTER CONTROL
C_2	FERMENTER DRIVE
C_3	VACUUM SEPARATOR FEED TEMP.
C_4	VACUUM SEPARATOR TEMP.
C_5	TIMER

PUMPS:	
$P_1 - P_2$	ACID - BASE DOSING
P_3	MEDIUM FEED
P_4	FERMENTATION BROTH EFFLUENT
P_5	SOLVENT RECIRCULATION
P_6	REGENERATED SOLVENT FEED
P_7	SOLVENT EFFLUENT
P_8	EFFLUENT RESERVOIR SOLVENT RETURN
$P_9 - P_{10}$	VACUUM SEPARATOR FEED
P_{11}	REGENERATED SOLVENT RETURN

vaporization unit (V_{13}) is operated under vacuum at *ca.* 75°C , conditions at which essentially all the ethanol is removed from the solvent. The ethanol is recovered in the condenser (V_{15}) while the regenerated solvent is returned to the solvent reservoir for re use. The packed bed solvent regeneration column (V_3), previously used to strip ethanol from the solvent in the 1.3 L system, is also incorporated into the present system; however, its use has not been necessary.

RESULTS AND DISCUSSION

Following extensive testing of the system, an extractive fermentation run of over 400 hours was carried out. The main objectives of this run were (i) to demonstrate the thermal and chemical stability of the solvent through repeated solvent recovery and (ii) to determine the ethanol productivities, based on ethanol recovery from the effluent solvent stream, which could be achieved.

Figure 2 illustrates the time course of this experiment with respect to the glucose, cell and ethanol concentrations in the fermentation broth; **S** , **X** , and **P** respectively. Major changes in operating conditions are indicated by vertical dashed lines. Fermentation conditions that were kept constant were: agitation speed 150 rpm; temperature 30°C ; pH 4.0.

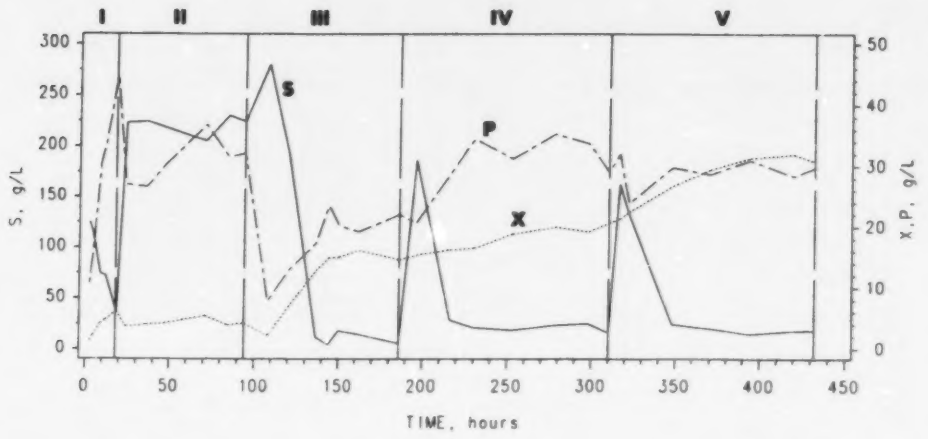

Figure 2: Concentration in the aqueous phase *vs.* time for extractive fermentation of 300 g/L glucose feed.

The different stages of the fermentation were:

I. Conventional Batch Fermentation (0-18 hours).

II. Conventional continuous operation (18-94 hours) with an average aqueous dilution rate of 0.04 h^{-1}.

III. Extractive fermentation (94-186 hours) with an average aqueous dilution rate of 0.04 h^{-1} and an average solvent dilution rate of 1.05 h^{-1}.

IV. Extractive fermentation (186-310 hours) with an average aqueous dilution rate of 0.11 h^{-1} and an average solvent dilution rate of 1.05 h^{-1}.

V. Extractive fermentation (310-432 hours) with an average aqueous dilution rate of 0.15 h^{-1} and an average solvent dilution rate of 2.10 h^{-1}.

Both the aqueous and solvent dilution rates are based on the aqueous volume of the system; the aqueous dilution rate is also based on the medium feedrate which is greater than the aqueous effluent flowrate due to conversion of the substrate to ethanol. During all stages of extractive fermentation, the solvent recirculation rate was 20 L/h.

The steady-state data from the chemostat and extractive fermentation stages are shown in Table 3. The **extraction efficiency** is defined as the ratio of the amount of ethanol removed in the solvent stream relative to the total amount of ethanol produced. The **ethanol productivity** of the system is based on the aqueous volume of the fermenter and the amount the ethanol recovered from the solvent stream by the flash unit and condenser only. Approximately 90% of the ethanol in this stream was recovered as condensate. The composition of the condensate was between 65-85% (by weight) ethanol with the remainder being water. The major source of this water was water vapour in air entrained in the line from the staged separation column.

Table 3: Steady-state data for conventional and extractive fermentation of 300 g/L glucose feed.

PARAMETER	FERMENTATION STAGE II	III	IV	V
Aqueous Dilution Rate, /h	0.04	0.04	0.11	0.15
Residual Glucose Conc., g/L	221.	10.8	22.0	19.0
Aqueous Ethanol Conc., g/L	30.7	20.5	32.1	29.4
Cell Conc., g/L	4.2	14.7	18.6	30.1
Cell Viability, %	95	84	87	81
Solvent Dilution Rate, /h	--	1.05	1.05	2.10
Extraction Efficiency, %	--	89	70	73
Ethanol Productivity, g/Lh	--	3.5	7.8	11.6

During this experiment, the system was being operated with a reservoir of 40 L of solvent, and with the solvent circulating in a closed loop (no bleed, no make-up). There did not appear to be any accumulation of toxic or inhibitory compounds (fermentation by-products) during the more than 14 days that the system was operated in extraction fermentation mode. Volatile by-products are expected to have been removed from the solvent, along with the ethanol, in the flash unit. It is possible that some non-volatile materials may accumulate in the solvent over the course of more prolonged extractive fermentation operation, although such compounds could be readily removed by the water stripper (V_3) as long as they were water-soluble (the solvent is virtually insoluble in water: < 30 mg/L at 30°C). No deterioration in the physico-chemical properties of the solvent were observed even though the solvent volume passed through the system (including flash unit) more than an estimated 50 times.

In summary, this work continues to show the continuous, stable and long-term operation of the extractive fermentation previously developed in this laboratory. The initial 1.3 L prototype system has been scaled up to a 7 L vessel with more sophisticated ancillary equipment, including a thermal recovery unit to separate the product from the extracting solvent. The solvent appears to have excellent physical/chemical properties in connection with the present application, and has shown no accumulation of inhibitory fermentation by-products in the present process lay-out and duration of operation. Experimental data are currently being used as the basis of a detailed economic evaluation of the process.

ACKNOWLEDGEMENTS

A contract from the Bioenergy Development Program of Energy, Mines and Resources Canada saved this project from being abandoned at a critical stage of the work. This support and the assistance of Dr. W.E. Lowe are gratefully acknowledged.

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The Monday luncheon speaker, Art Meyer was introduced by **Hon. Harold Neufeld**, Minister of Manitoba Energy and Mines, Minister responsible for the Natural Gas Supply Act, Minister responsible for the Manitoba Hydro Act and Minister reponsible for Seniors. The Minister is the Member of the Legislative Assembly for Rossmere.

Arthur E. Meyer, P.Eng. Vice-President and Director, Mohawk Oil Co. Ltd. Burnaby, BC.

Art graduted from the University of Saskatchewan in 1949, with M.Sc. Mechanical Engineering. He was employed by Royalite Oil Co. Ltd. from 1949 to 1963 in refining and marketing positions. From 1964 to 1977, Art Meyer operated as Managing Partner for Associated Engineering Services Ltd. in Calgary and Edmonton.

From 1978 to 1985, Art operated as President of RDC Research Development and Consulting Ltd. investigating alternate fuel opportunities for Mohawk. He is now employed by Mohawk Oil in general management and corporate development as well as continuing to manage RDC.

NOTES FOR SPEECH TO THE
1988 CANADIAN POWER ALCOHOL CONFERENCE

by

MR. ART MEYER
EXECUTIVE VICE-PRESIDENT, MOHAWK OIL CO. LTD.
BURNABY, BRITISH COLUMBIA

FEDERAL POLICY ON ALCOHOL FUELS

It is a pleasure to join the people who have continually supported the concepts of biomass energy here at Canpac '88. The issues are becoming better defined than they were back in '79 and '80 but the instincts we had then that aimed us at clean renewable fuels are being reinforced by growing scientific evidence that we are not only at risk due to OPEC's economic dictates, we are also at risk of messing up our planet unless we learn how to make energy from something other than fossil fuels.

Ten years ago it was potential oil shortage that drove our desire to produce liquid ethanol as a substitute for gasoline. RENEWABLE ETHANOL appeared to be desirable.

In the early to mid 80's some cities recognized that their auto exhaust smog could be controlled by blending oxygenates such as ethanol into gasoline - clean burning ethanol offered reductions in CO and unburnt HC.

More recently we have learned that lead in gasoline is a far more damaging ingredient than we earlier knew and it is obvious that high octane ethanol is a good solution for the manufacture of high performance gasoline blends to power the compact high performance fuel efficient late 80's automobiles HIGH OCTANE ETHANOL.

And in 1988 the world has recognized that the carbon mined from fossil fuels stored deep below the earth's surface when processed through car engines or thermal generating plants into CO_2 is forming a blanket in our atmosphere that is changing our climate and may cause unknown and undesirable changes to our lifestyle and our economics if not to our survival. NON CO_2 PRODUCING ETHANOL. Ethanol fuel would resolve that threat.

For ten years during the roller coaster ride on OPEC's oil price chart the one constant potential solution to each of the energy problems has been renewable, clean burning, high octane non CO_2 producing ethanol.

Canada has not developed very much fuel ethanol production since the first threatened oil shortages of '78 and '79. But I think we are all seriously aware of the desirability of developing an energy source that will be <u>continuously available at a decent price</u>, could be available in <u>all regions of Canada</u> from local biomass supplies and on a gradually increasing basis can solve all of our environmental problems.

The time has come to recognize that our future is not with tar-sands plants, Hibernia oilfields and more coal mines. A different series of solutions must be found.

The vast sums of money that are presently aimed at fossil fuel projects should be redirected instead to ethanol projects, hydro electric generators, safe nuclear generators, electric car research, and continued work on hydrogen. Clean fuels, solar and wind energy must be our objectives.

Mega projects will be required in water management for hydro and irrigation so there need not be fear of lost construction and jobs.

Technology is required for improved nuclear and biomass conversion processes.

And meanwhile, no matter how fast we move, oil and gas demands on Canada's dwindling available supplies are going to cause continued activity by those that are motivated to pursue the conventional oil and coal business.

When ethanol demand throughout the world exceeds the ability to produce grain it will be necessary to perfect the existing processes for conversion of wood and straw to ethanol and other hydrocarbon chemicals. This in turn requires improved forest management and reforestation projects and possibly the development of large forest farms which will reabsorb vast quantities of CO_2, revitalize the soil and provide the feedstock for ethanol.

An election has been called and so far I haven't determined that solving the environmental threat of excess CO_2 has become a commitment for Canada. We do know that the lead phasedown has been advanced to 1990.

In a statement on energy policy presented by Mr. Mulroney in August, 1984 in Halifax, the promise was made that "There is a very real opportunity for fuel alcohol to be used in Canada as an alternate octane booster in gasoline. A Progressive Conservative government will set up a special programme to encourage the use of alcohol as a lead substitute for octane boosting".

But we have not yet convinced our MP's in Ottawa that they must mandate the use of cleaner burning fuels and alternate energy. Perhaps we should all propose a tax on dirty fuels which would then be used to pay for development of clean fuels.

Development of the Fuel Ethanol Industry in Canada has so far been mostly theoretical in every region except Manitoba.

I am hopeful that the last ten years has been a research period and that we are now ready for development.

Roy Piper, Chairman Session 3

Director, United Grain Growers

Roy Piper graduated from the University of Saskatchewan in 1968 with a degree in B.Sc.Chemical Engineering and worked as a Process Engineer for Shell Canada in a refinery and computer operations. In 1976, Roy returned to farming at Elrose Saskatchewan, where he is a grain and special crop producer.

Mr. Piper is also a Director of Investors Group Inc. , Chairman of National Task Force on Farm Energy Management and Vice-Chairman of Western Grains Research Foundation.

Ken Beswick, Chairman, Alberta Grain Commission

Ken Beswick graduated from the University of Western Ontario in 1970 with a Masters of Business Administration after completing a B.Sc. (Agriculture) from the University of Manitoba in 1968. Ken farmed at Spring Coulee for 17 years and also did some teaching at the University of Manitoba. He was appointed as a member of the Alberta Grain Commission in 1985 and Chairman in 1986. Ken chaired the Government of Alberta interdepartmental committee of fuel alcohols.

Martin Wrubleski, Acting Director, Agricultural Engineering Branch, Saskatchewan Agriculture.

Martin graduated in Agricultural Engineering from the Univerity of Saskatchewan in 1965 and completed a Masters at the School of Engineering, University of Guelph in 1970. For the past two years Martin has been the manager, Agricultural Engineering, Extension Service. In 1981-82, he was a member of a design team task force for an ethanol plant in Saskatchewan. Martin has also been Chairman of the Canada Committee on Agricultural Engineering Services Expert Committee on Energy.

Laurie Baker, Lecturer, Macdonald College of McGill University.

Laurie has taught in the areas of Farm Business Management, Agribusiness, Agricultural Marketing and Management, Economic and Resource theory. He graduated in agriculture from Edinburgh and studied in Aberdeen before coming to the University of Manitoba to graduate in Agricultural Economics in 1977. From 1968 to 1972, Laurie was employed in agribusiness, working for Chipman Chemicals Inc. and Canadian Canners Ltd.

Barry Beale, Policy Advisor in the Liaison and Planning Branch, Ontario Ministry of Energy.

A native of Saskatchewan, Barry grew up in Vancouver before moving to Toronto. He holds a Bachelor of Commerce degree from Queen's University and a Masters in Environmental Studies from York University. Barry's experience in the alternative transportation fuels industry, including oxygenated fuels, dates back to 1980. He worked in this area as a consultant, as an employee with the Ontario Energy Corporation and for the past four years at the Ministry of Energy.

ALBERTA STUDIES AND POLICY DEVELOPMENT

by

MR. KEN BESWICK
ALBERTA GRAIN COMMISSION
EDMONTON, ALBERTA

Thank you very much, Roy. It's a pleasure to be invited to talk to you today. A bit of a challenge to have the opportunity to talk to you right after lunch. See if I can wake you all up.

Going to do three things, basically. Going to talk to you about fuel ethanol, obviously, but I'm going to break it up into three parts. I'm going to explain to you why we examined the issue; how we examined the issue; and then talk a little bit about some of the conclusions that we came to.

A year ago last June, in June or July of 1987, it occurred to us that the whole issue of alcohol, ethanol in particular, as used for fuel was going to become an issue, was becoming an issue, and that we had to take a look at it again. It's been said two or three times this morning, in one way or another, that ethanol re-emerges from time to time, and it catches the imagination and the interest of people in the industry. Well, with the low grain prices that we've had the last several years, 1987 was another one of those times.

Rather than have a whole bunch of Aggies take a look at the issue, let me bring this to mind with a story - it's about a young man, a very young boy, sitting beside the road. Several, two or three, men pass him and they discover that this young boy is crying very, very seriously, and it has something to do with this dead elephant that's laying beside him. One of the men said, "Isn't that tragic, we should have a great deal of sympathy for that young man because he's crying over the death of his charge, that poor elephant". The other man said, "I have a little different point of view - perhaps he's crying because he has to bury it".

In regard to fuel ethanol, your point of view on fuel ethanol has a lot to do with some of the conclusions you come to. Can we have the first slide up.

I suggested to our Minister that we have a committee composed, not of a bunch of Aggies, people who have an interest in the grain industry, but people who might present, might cause everybody to present a little more balanced, a little more objective point-of-view. We had members on our committee from the Department of Agriculture, the Alberta Grain Commission, from the Department of Energy in Alberta and from the Department of Economic Development. We didn't have anyone from the Department of the Environment, that was a oversight in the beginning. By the time we discovered that we needed someone from the Department of the Environment, we had gone so far that it was too late then to bring somebody up to speak, so we went without.

That's why we decided to take a look at fuel ethanol, and instead of coming up with decisions, instead of coming up with alternatives in the beginning, we were sort of pure about this - we took a pretty pure approach, a very disciplined approach, I think. We established criteria up front without ever taking a look at the issue of ethanol itself first. These issues, there, the ones in front of you on the screen, are what we called our main criteria. Each and every one of these characteristics, these criteria, had to be met by any particular programme or policy or alternative in respect to fuel ethanol. Anything that we did with fuel ethanol had to meet each and every one of these before it would be considered at all.

Since we were really talking about an agricultural programme, or at least, since that's where the interest was and that's where the pressure was to take a look at ethanol, we decided that at the very least, anything that we recommended in fuel ethanol had to either maintain or increase the markets for agricultural products in Alberta. In addition, anything that we did with alcohol fuels had to improve or maintain the level of environmental protection. We said that anything we did with alcohol fuels must retain or improve the safety associated with the handling of fuels. We said that anything we did with alcohols had to comply with current government regulation and legislation. It also had to result in some sort of a net positive economic benefit for the province. We're looking at it from a provincial point-of-view, and we were not crazy about any programme or policy with alcohol fuels that would somehow take something away on a net basis from the province. Please note that we did not say that all sectors of the economy had to benefit, we just said that there had to be a net benefit overall. If farmers, for example, benefited more than the petroleum industry, that was fair dinkum. That was O.K. That would be something that we would consider. And lastly, we said that any programme or policy in respect to fuel alcohols must not result in long-term net public financial support. Said it's O.K., people have suggested that we have to kick start this industry, and that's really what we're talking about - that might be acceptable, but in the long run, net public financial support wasn't something that we were interested in.

Just to review for a moment, each of those six criteria had to be met - if it didn't meet each and every one of those criteria, that particular alternative would not be considered further.

In addition to those, what we called our 'musts', things that must be satisfied by ethanol policy, alcohol policy, we had a bunch of other subsidiary criteria. These were things that we would like to have happen. These were things that we would like to have met by an alcohol policy. Any policy that we considered that met these to a greater extent than other alternatives would be rated more highly. These are 'shoulds'. We said that these things were preferable, but they weren't mandatory. We said that any policy in respect to fuel ethanol should not require financial assistance from the province greater than that which is currently offered for other alternative transportation fuels. We said that it really would be a good idea, we thought it would be a nice idea, if an ethanol industry could survive when grain prices were equal to, equivalent to barley at $75 or $80 a tonne. Please note that the equivalent is in there, we did not say that barley was the most appropriate feed stock - I don't

think we believe that, but we had to pick one crop, and since barley is the one that's now produced in significant quantity in our province, and is available as a feed stock, we based it on barley and on a starch basis, on a sugar basis - wheat or some other product would be priced differently, but equivalent to $75 or $80 a tonne for barley. The reason we picked the $75 to $80 a tonne level, price level, was because of the difficulties in the prices of feed grains last year. When we started to look at this, barley was in the order of $50 a tonne. It occurred to us that if we were to analyze ethanol and find that it was an appropriate industry that it was economically viable based on present day prices for feed grains for the feed stock for that product, in the long run we probably would not have done anybody any good because $50 a tonne was far too low a price to support the feed stock industry itself. We're not going to have barley producers in the business in the long run, if all they can get is $50 a tonne. So what price do you pay? You don't like $50, what price do you pay? $150 sounded really nice - we like that price, but thought that maybe, probably inappropriate in the long run as well, and we compromised. We said, well, since the production costs of barley are in the $75 to $80 a tonne level in there someplace, we can argue whether it's a little higher or a little lower - that's the price we will use". It's not a very attractive price, but at least in the long run, it's a price high enough to at least support the feed stock industry itself, the barley industry. We probably have barley production in that province for a long time at the level of $80 a tonne. One of our other subsidiary criteria was that ethanol should not increase the cost of fuel to the driving public. If it did increase the cost of fuel to the driving public, we wouldn't refuse to consider it. It would just be less attractive. It should increase economic diversification and balance regional growth in the province. In other words, if you can get some regional development kickers in here, we are going to look at it more favourably than if the ethanol industry were created and built inside or adjacent to our major cities. It should increase employment in Alberta - we thought that would be a nice thing. It should be compatible with current refining and distribution procedures for petroleum products. It should achieve product acceptance by the car manufacturers and the consuming public; it should achieve product demand and acceptance by the fuel marketers, and somehow we should recognize the implications of developments in other provinces and in other countries.

Those were developed first - all those criteria were the criteria that we used to analyze the things that came next. We hadn't really talked about ethanol very much - we hadn't talked about alternatives - we hadn't talked about policies at that point. There was great resistance to the idea of developing those first - everybody wanted to talk about alternatives first, but we chose not to do that.

Our conclusions: The conclusions we came to based on those criteria, and these are one for one, was that the market for grains grown in Alberta would increase proportional to the production of ethanol. Now that seems like an obvious one, but it's not. It's not necessarily obvious at all. If, for example, the production of ethanol used such vast quantities of grain that you got such a terrific price response that barley or the feed stock priced itself out of the feed grain market, and our feeding industry, our livestock feeding industry, were to decline as a result, you might not necessarily get an increase in the volume of grain sold within

the province. Obviously, ethanol production is dependent upon market acceptance for the fuel. You can produce it, but you can't produce it for very long unless it's consumed by somebody. But that's kind of an obvious one. Based on the information available to us, we concluded there were both positive and negative environmental effects from displacing hydrocarbons with alcohol in low percentage alcohol-blended fuels. We said there were positive environmental aspects of using alcohol fuels and there were negative aspects of using alcohol fuels - there were both. The balance is probably positive, but it is not nearly as positive as some proponents of ethanol would have us believe. It's no magic panacea.

We concluded that the use of fuel ethanol does not reduce the safety associated with the handling of fuels. We concluded that ethanol-blended gasoline can comply with current government regulations - it doesn't have to, but it can. It depends on how you tailor the gasoline; it depends what the vapour pressure of the finished gasoline is. We also concluded that the minimum cost to the treasury of our province was greater than the maximum benefit to agriculture, and evidence, we couldn't find evidence to demonstrate that fuel ethanol would provide a net positive economic benefit for the province. Now remember, that these are conclusions that each and everyone had to be - the answer to which had to be 'yes', before we would consider the alternative, and that one was quite a definite 'no'.

The sixth one was another 'no'. If fuel ethanol were to be cost competitive with gasoline, long-term net financial support would be required. Those were our main criteria. We had four "yes's"; we had two resounding "no's".

The conclusions to our subsidiary criteria. We concluded that financial support greater than that currently offered for other alternative transportation fuels would be required to support, or to drive, or to create an ethanol industry in the province. We said that an ethanol industry would not be viable in Alberta when grain prices were the equivalent of $75 to $80 a tonne for barley, and when wholesale petroleum prices were 20¢ a litre, and that was the price that we were talking about at that time. The price for petroleum products, the wholesale price of petroleum products at that time was 20¢ a litre and that was the bench mark that we used. At those prices and in the absence of subsidies, the use of ethanol would require, would result in an increase in fuel prices to the driving public. It's more expensive than gasoline. We said that we don't want the price of fuel to be higher to the driving public, and if you don't provide incentives, if you don't provide subsidies of some sort, someone's going to have to pay for that, and that's the drivers.

We concluded that economic diversification and balanced regional growth within Alberta could, not would, but could be enhanced with an ethanol industry. Could be, and that presumes that the ethanol production facilities are, in fact, located in the outlying region. Presumes that they will not be located within urban centres or adjacent to urban centres, and that's a presumption that's not necessarily true, not necessarily accurate. Every reason to believe that ethanol production facilities, might just as easily be located in urban centres as in regional centres, at least in the absence of government direction in terms of where they are located.

And it's very unlikely that the Province of Alberta would get involved in directing where the plants would be built, if they in fact were built. Although regional employment opportunities would be created by the ethanol industry, we couldn't determine that the establishment of a fuel ethanol industry would either increase or decrease overall employment opportunities in Alberta - we didn't know. That's not a 'yes' and that's not a 'no'. We just said, "we don't have the information - we don't have the talent within our committee to take a look at all the different industries that are affected by this". We know that there are going to be jobs created in an ethanol production industry - we also know that it's likely to result in some sort of loss of jobs in the petroleum industry. What about the feeding industry; what about the grain transportation and handling industry - it was too big a question for us to look at, and we just said, "we don't know".

We conclude that current refining and distribution procedures are not compatible with alcohol-blended fuels. We didn't say they would not be, or could not be, we said, "they are not at the present time compatible with what was necessary for alcohol-blended fuels". Vehicle manufacturer approval for ethanol blends has been increasing until we could only find one manufacturer in 1986 that was known to be prepared to void warranties if ethanol was used. In other words, that's a 'yes'. At one time there were an awful lot of vehicle manufacturers who didn't like alcohols, they disliked methanol much more than they disliked ethanol, but even in 1986, it wasn't universally accepted that ethanol could be used in vehicles.

We also concluded that there are some marketing barriers to the larger gasoline marketers in particular offering ethanol gasoline or ethanol/methanol gasoline fuel blends to their customers. Some concerns about the method and the cost of distribution, compatibility with other gasolines, current economics and the need to maintain a high level of customer satisfaction.

And finally, subsidy criteria in other provinces, and in the United States make it highly unlikely that fuel ethanol producers in Alberta would be able to export their production. It's basically a way of saying that ethanol can't move into Saskatchewan because of the restrictions on policy in Saskatchewan; ethanol can't move into the United States because of tariffs on the movement across the border. Next slide:

Insofar as the benefits to agriculture - that's a Table showing our conclusions on the overall benefits to agriculture, the overall effects on agriculture at least. Please recognize that we did not include in here very much on the effects on federal policies on agriculture - that's really the federal government's business, and if we increase the cost of federal programmes, it's not our concern - if we reduce the costs of federal programmes because of our ethanol industry, again, that's not our concern.

We said that you will, if you use grain to produce ethanol, get an increase in consumption of grain and you will get, therefore, an increase in the production of grain. You're also going to get, because of that increase in consumption, some price response - we're to get an increase in the price of grain. So really, multiplying increase in production by the increase in price gives you some kind of a gross benefit to

grain producers because of producing ethanol, because of the ethanol industry. We said that was $35,000,000. However, if you're going to increase the production of grain, you don't do it for nothing - it costs something to produce every tonne of grain, and it will cost something more to produce an extra tonne of grain. So remember when I said that we used the price of $75 to $80 a tonne because that was roughly speaking the production costs of barley. That $35,000,000 may be nearly offset by the increased production costs for barley, and that's reflected in our estimate of $29,000,000 additional for that production that it would take to increase the production of barley. So you've got a $35,000,000 gain, you've got a $29,000,000 cost of producing that. You've got a $6,000,000 benefit because of the potential benefit on distillers grains to the livestock industry. We said we don't think that at the present time livestock producers, livestock feeders are going to pay as much as they should for distillers grains, and insofar as they are getting a product at something less than its equivalent price, basically compared to soybean meal, there's a benefit. They're getting a benefit - paying less for something than it's worth.

That was $6,000,000 we calculated. We also said that since we've estimated that the cost, that the price of feed grains was going to increase, we said there was going to be a price response because of the increased consumption, our feeding industry is going to have to pay more for their feed grains, and that's going to be a cost. It would cost a million dollars or more extra for our feeders to buy grain. I guess it's only fair to say that anything that jeopardizes the feeding industry is something we're not crazy about. The feeding industry is a major industry in Alberta - quite frankly the ethanol industry is a Johnny-come-lately, and quite small in comparison, and if you recognize that the feeding industry in Alberta is one of the major parts of the foundation upon which the Alberta economy is based, we're very, very careful and we're very, very careful to point out any disadvantages that might accrue to our livestock industry. That was a million dollars.

In total, adding them all up, the pluses and the minuses, we said there's likely to be a $10,000,000 net gain to agriculture in Alberta. Remember the $10,000,000 number - that one's important.

Next Table: Balanced against the $10,000,000 gain to agriculture - $10,000,000 net gain to agriculture, is some sort of government cost because ethanol costs a lot more than petroleum based fuels. We said that ethanol is probably going to cost on a large scale basis 45¢ a litre to produce. We took a look at all of the information we could find, all the different studies we could find both in Canada and United States and tried to use our own best judgment on who was right, or at least how close they were to being right. It's a little like the boy and the elephant - it depends on your point of view, whether you'll accept the 20¢ a litre numbers that some people suggest, or whether you'll accept the 75¢ a litre numbers that other people suggest - it's your point-of-view, and we tried to use our best judgment in getting some kind of answer to that.

We said 45¢ a litre. Given that the wholesale cost of petroleum last winter was 20¢ a litre, it's a relatively simple calculation to come up with 25¢ a litre difference. And we said that all we need is a difference because we thought that probably ethanol made an appropriate fuel

and it was probably an efficient fuel. We weren't talking about any significant, if at all, mileage differences - so we said a litre of ethanol mixed with gasoline is equivalent to a litre of gasoline in terms of driving - in terms of mileage and things like that. 45 less 20 is 25¢ and we said that somehow someone's going to have to pay 25¢ a litre to make ethanol equivalent in cost to the wholesale price of gasoline. We assumed two sorts of market penetration levels. One with straight ethanol or straight gasohol, 10% ethanol and gasoline. We said that the maximum you're likely to be able to get, we don't think it's likely that you'll get a 30% market penetration, that's a maximum - 30% market penetration of a 10% gasohol blend. The second situation was 100% market penetration of a 3/5 EM blend. Those were maximums. Kind of convenient, because the amount of ethanol used in 100% 3/5 blend is exactly the same as the amount of ethanol produced in a 30% market penetration with 10% ethanol. It made the calculations easy and that played no small part in the way we chose those numbers.

At 25¢ a litre, it would have cost the provincial government $33,000,000 in terms of direct financial incentives to make the cost of the ethanol produced equal in price to gasoline at 20¢ a litre. Remember I said that agriculture related benefits were $10,000,000, and to spend $3 to get one back we didn't think was a terribly good idea. The subsidy is far less in terms of ethanol if you go with an ethanol-methanol blend. It only requires about $11,000,000 for the ethanol portion, then you have to subsidize the methanol one way or another - if you don't subsidize the methanol, you have to subsidize the total blend - one way or the other, it ends up costing you $22,000,000.

Those were the costs - $22,000,000 for an EM blend and $33,000,000 for an ethanol blend merely to make the cost of ethanol equivalent in price, or the cost of an ethanol-methanol blend equivalent in price to the wholesale cost of gasoline.

In the next Table, we said that that wasn't necessarily enough. We found no manufacturer, with the possible exception of Mohawk, to tell us they were interested in ethanol or methanol or a combination of two of them, at prices equivalent to the cost of gasoline. No one. And whether that's justified or not, is in many ways besides the point. The point is they are the ones who sell the fuel, and you have to recognize their point-of-view.

E10, we said it would cost 25¢ a litre to subsidize ethanol itself, so that it would sell, so that the fuel marketers would be indifferent on the basis of input costs. That's not enough. We have to have something else. We didn't know what those quantities were, we had various petroleum consultants tell us what those numbers were, but all I'm suggesting to you is that that subsidy, it's something greater than that subsidy in order to make the fuel marketers interested in using it. And that's really all that that Table says on top - it says it in two or three different ways, and talks about independence, and talks about majors and all the rest of it - but it just suggests that those numbers A, B and C are added to the incentives, the financial incentives we talked about and those financial incentives were minimums - it will be something more than that.

Now before we leave it, and I'm just about done, because that's really the conclusions we came to, and that's really where we left it, I'd like to talk about one other thing, and that's really the kinds of statements that are made on the bottom of that page. Various peoples, various positions and points-of-view on ethanol in terms of what's required in subsidies and all the rest of it depend on the production costs and the marketing value of alcohols or ethanol in gasoline. When we're talking about a 3/5 blend, for example, recognize that the effects on the cost of any marketing premiums or marketing discounts that you can get for the ethanol portion is highly leveraged, leveraged 30 to 1. If you can get a quarter of a cent premium for the ethanol you have due to the fact that you have ethanol in the gasoline, any financial subsidy that's required diminishes rapidly. It disappears in a hurry. The converse is also true. If for some reason, you have to discount your gasoline because you have got alcohols in it, whether that's ethanol or methanol, the subsidy that's required to drive that in the market place is leveraged the same way in the other direction. The incentive that's required to make ethanol saleable, or methanol saleable, increases dramatically. So I guess I'm suggesting to you that it really depends on how successful the petroleum marketers or governments, or somebody else is in convincing the driving public that alcohols are suitable gasolines, are suitable fuels, and may even be superior fuels. If we can do that, we've probably got an industry - it's really that simple. If we can do that, we've probably got an industry. If we can't do that, we probably don't.

Thank you very much.

1) Must maintain or increase the markets for agricultural products;

2) Must equal or improve the level of environmental protection;

3) Must retain or improve the safety associated with the handling of fuels;

4) Must comply with current government regulations and legislation;

5) Must achieve a net positive economic benefit for Alberta;

6) Must not require long term net public financial support.

Subsidiary Criteria

A policy in respect to fuel ethanol should ;

- not require direct financial assistance from government greater than that which is currently offered for the development of alternative transportation fuels;
- develop an industry which is viable at a range of grain prices equivalent to barley at $75-80/tonne;
- not increase the cost of fuel to the driving public;
- increase economic diversification and balanced regional growth within Alberta;
- increase employment in Alberta;
- be compatible with current refining and distribution procedures;
- achieve product acceptance by car manufacturers and the consuming public;
- achieve product demand and acceptance by the fuel marketers;
- recognize the implications of developments in other provinces.

CONCLUSIONS

1. The market for grains grown in Alberta will increase proportional to the production of ethanol. Ethanol production is dependent upon market acceptance of ethanol-blended gasoline.

2. Based on the information available, there are positive and negative environmental effects from displacing hydrocarbons with alcohol in low-percentage alcohol-gasoline fuel blends in Alberta.

3. The use of fuel ethanol does not reduce the level of safety associated with the handling of fuels.

4. Ethanol-blended gasoline can comply with current government regulations and legislation.

5. The minimum cost to the public treasury is greater than the maximum benefit to agriculture, and evidence does not exist to demonstrate that fuel ethanol would provide a net positive economic benefit for Alberta.

6. If fuel ethanol were to be cost competitive with gasoline, long-term net public financial support would be required.

7. Financial support greater than that currently offered for alternative transportation fuels would be required to support an ethanol industry in Alberta.

8. An ethanol industry would not be viable in Alberta when grain feedstock prices are equivalent to $75-80/tonne and the wholesale price of gasoline is $0.20/litre.

9. At these prices and in the absence of subsidies, the use of ethanol would result in an increase in fuel costs to the driving public.

10. Economic diversification and balanced regional growth within Alberta could be enhanced with an ethanol industry.

11. Although regional employment opportunities would be created by an ethanol industry, it has not yet been determined that the establishment of a fuel ethanol industry in Alberta would result in an increase or decrease in provincial employment.

12. Current refining and distribution procedures are not compatible with alcohol-blended fuels.

13. Vehicle manufacturer approval for ethanol blends has been increasing until only one manufacturer in 1986 was known to be prepared to void warranties if related mechanical problems developed.

14. There do appear to be some marketing barriers to larger gasoline marketers offering ethanol-gasoline or ethanol-methanol-gasoline fuel blends to their customers, such as concern about the method and cost of distribution, compatibility with other gasolines, current economics and a need to maintain a high level of customer satisfaction.

15. Subsidy criteria in other provinces and the U.S. make it unlikely that fuel ethanol producers in Alberta would be able to export their production.

AGRICULTURE RELATED EFFECTS

$ 34.6 million	Gross Revenue Increase
(29.1 million)	Increase in variable Production Costs ($70)
6.1 million	Potential benefit from distillers grain
(1.2 million)	Cost to domestic livestock industry due to price increase
$ 10.4 million	Net potential agriculture-related benefit

LOWER BOUND ESTIMATES OF ETHANOL SUBSIDY COST

	ETHANOL SUBSIDY COST	METHANOL SUBSIDY COST	TOTAL COST TO GOVERNMENT
Scenario 1 30% penetration 10% ETOH $0.25/litre subsidy	$33 million	0	$33.1 million
Scenario 2 100% penetration 3%/5% blend $0.083/litre subsidy to ETOH $0.05/litre subsidy to MTOH	$11 million	$11 million	$22 million

Note: Calculations assume there are no additional costs for blending and that no premium can be captured on the retail price. A quarter cent per litre change in the blender's costs or the retail price would cause a change in the subsidy cost of $3 million for the ethanol blend (Scenario 1) and $11 million for the ethanol/methanol blend (Scenario 2).

ROUGH ESTIMATES OF REQUIRED ETHANOL SUBSIDY
FOR INPUT COST EQUIVALENCE WITH GASOLINE

	Independent Marketers		Refiner/Marketers
	Indifference on input costs	Indifference on input plus marketing and distribution costs	Indifference on input, marketing and distribution costs
E10	$0.25/L	$0.25/L + A	C
3/5 blend	$0.08/L	$0.08/L + B	C

Note 1: Amounts A, B, and C are unknown. It is believed that B is greater than A, and C is much greater than B.

Note 2: Should blending and conversion costs increase the total cost of the blended fuel by $0.01/L, the required subsidy for ethanol in an ethanol/methanol blend would increase from $0.08/L to $0.42/L. The opposite effect would result if an independent marketer were able to attract a $0.01/L premium by marketing his product as a superior fuel. Because of the small component ethanol would represent in such a blend, the maximum price the blender could pay for ethanol, and hence the required level of subsidization, is highly "levered" against small changes in the weighted average price he can afford to pay for the three fuels blended together. The degree of risk this introduces means that, in the case of an ethanol/methanol blend, making blending attractive on a widespread basis would require a significantly higher subsidy than indicated by this simple calculation.

DIRECT COSTS/BENEFITS

Agriculture Impacts	Discussion Paper	Touche Ross
Gross Revenue Increase	$ 34.6 million	$10.0 million
Potential Benefit from Distillers Grains	6.1	0
Cost to Domestic Livestock Industry	(1.2)	0
Incremental Variable Production Costs	(29.1)	(7.6)
Agriculture	10.4	2.4
Ethanol Impacts		
Gross Revenue Increase	0	67.1
Variable Operations Costs	0	(43.3)
Government Impacts		
Ethanol Subsidy Cost	(33.1)	(38.4)
Total Net Direct Impact	(22.7)	(12.2)

SASKATCHEWAN - ETHANOL PRODUCTION AND MARKETING INCENTIVE PROGRAMME

by

MR. MARTIN WRUBLESKI
ACTING DIRECTOR, AGRICULTURAL ENGINEERING BRANCH
SASKATCHEWAN AGRICULTURE
REGINA, SASKATCHEWAN

Saskatchewan, I guess, is kind of in the middle between the two different perspectives on ethanol policy. I suppose those you've read ahead in the papers, you already have a pretty good idea of what I'm going to be talking about, so I think I can be brief. And I guess it's by my nature, that I am brief, so I guess we'll catch up some time here.

But, I guess, as I was saying, we are sort of in the middle on our perspective on energy policy, but in summary it probably does lean more towards the Manitoba approach. So I guess with that sort of introduction, then I'll explain it in a little bit more detail.

The interest in ethanol has been high in Saskatchewan for the last ten years. Of course, the rising energy costs and the need to market grain, and the interest in energy security were early significant factors in that interest. And, of course, as the grain prices dropped and technology appeared more feasible, and lead phased out as well, presented opportunities. But I think, and I'll explain this a little bit more later, it would seem that ethanol production could serve as a catalyst for diversification of the agricultural economy, rural economy in Saskatchewan. The recent grain price trends and petroleum product price trends have not been in favour of ethanol. I think the belief is still there that the overall underlying long-term trends of increasing rural price for energy and decreasing - I don't feel good about saying this, but it seems that the decreasing rural price for grain has served to maintain interest in ethanol production.

Background Studies

So we'll just give a brief outline of the results of studies leading to the policy development and try to explain the policy and the recent changes, and describe some of the specific developments arising from the policy. Over the last three to four years, several internal and external studies were undertaken to examine some of the following issues. These are the gasoline and ethanol-methanol market issues and relationships; the blended gasoline quality issues; octane related issues; engine performance issues; legislative issues; cost of production of ethanol relative to scale and relative to grain prices, relative to operational costs and relative to energy prices; and cost reductions which might result from integration with feed lots - of course the possibility for integration with a petrochemical producer; the environmental issue - so you can see that even though we did it in a different way, a different series of studies in Saskatchewan, a lot of the obvious same issues that were examined in Alberta. And of course, at the same time, industry has shown that ethanol and ethanol-methanol

blends could be successfully marketed. So I guess, we looked at the same data, if you like, then we came up with conclusions which may be little different than what has happened in Alberta. So the ethanol production marketing incentive policy was then based on those conclusions.

There is no doubt that the industry did need incentives to encourage the required private investment. Since that was recognized, and it was faced head on, we went ahead and put them in, and what follows here is more the reason why. Within the framework of incentives, the scale and location of the facilities should be left to the private sector. Therefore the decision was made not to get involved in financing - the front end financing of production facilities, but instead make the incentive available to the fuel marketer. But I guess I could just add to this then, left it open for the federal government to, for example, get involved in capital funding, through the WDO, for example, for which they are in the process of doing.

The programme, and underlining discussions with proponents was meant to encourage regional scale projects to serve as a catalyst for other rural development projects. And maybe for those who don't know Saskatchewan that well, this has certainly been a lacking situation in Saskatchewan. Not so much in Manitoba, but even then, Manitoba did something like they did at Minnedosa. Certainly Alberta has been much more diversified, and they have done their own kinds of diversification with support for irrigation and so on. And I suppose you may even say for the petrochemical industry itself. So, the different provinces have different needs and you have to believe as in the case of Saskatchewan that the development of rural areas has been something that's been let go too long, and of course, may be one of the reasons even Ken has mentioned about federal government grains policy, but be that as it may. There it is, and some catching up needs to be done in terms of diversifying the Saskatchewan rural economy. So, ethanol may be one way - there was one way that was seen as a catalyst, an example to further possibilities that might be there.

And of course, as Del has mentioned, and many others have mentioned, we have to allow ethanol to come into the market in manageable quantities and certainly to recognize that ethanol production is more economical on a larger scale, or even possibly integrated with petroleum refineries as was suggested earlier. Then we've heard a little more detail this morning of those economic analyses. Integration with feedlots was shown to improve the economics, over smaller scale ethanol production facilities. Consumer acceptance of ethanol and ethanol-methanol blends, at the time we were doing the studies, was not that clear-cut. It would appear sufficiently conclusive to warrant a go-ahead, and of course, now, as we have moved along, as you have heard from Mohawk, consumer acceptance does appear to be mildly successful for them and is not considered to be a significant issue at this point.

A straight forward procedure was developed to allow payment of the incentive as a deduction from gasoline taxes remitted to the province by the gasoline marketer. Finally, just about finally, environment issues were pretty well neutral to use of ethanol in Saskatchewan, because of the smaller quantities, it's a less populated province - wide open spaces and

so on - so the analysis that we had seen done by the federal government indicated that it was probably neutral to the environment in Saskatchewan. That's not to say that it would be neutral in a more highly populated area, but certainly then, nevertheless, that the lead phase-down does provide an opportunity for ethanol.

So I guess I might just add that some more comment, that despite all that we have heard pro and con by the speakers, or seen by industry or government, we have as I indicated before, the two opposite approaches of our neighbouring provinces, government did feel that it should do something, and perhaps not really being able to predict just where it might be.

The Policy - 1987

In 1987, in October, the government announced the incentive of 4¢ per litre and that's to be paid to the marketer of a 10% blend and a proportion of the incentive of 1.2¢ per litre for an E3M5 blend. Of course, this is equivalent to an incentive of 40¢ per litre of ethanol.

The incentive is paid to the marketer as a grant from Saskatchewan Agriculture, and that's in recognition of the benefit to the farmer and the rural economy of increased development and grain sale. It recognizes that it is up to the marketer to maximize the market by advertising ethanol-blended products while passing along a significant part of the incentive to the ethanol producer. The policy requires that ethanol must be produced in Saskatchewan from Saskatchewan grown grains.

The ethanol producer cannot qualify for the incentive directly. In other words, the producer must enter into a contract with the marketer to benefit from the incentive.

I guess it goes without saying that policies like this will be reviewed as part of the annual budget review process to determine if changes are necessary to account for changed ethanol production costs or changes in world oil prices. Of course, governments can review. However, having said that we believe the incentive level is the correct one for the forseeable future.

The Policy - 1988

Changes can be made. Announcement of the policy created a surge of interest by many groups with at least six groups reaching the stage of developing feasibility studies. Then ongoing study by the industry and changes in the market resulted in requests for change in policies. So the first part of that is that even though the program was open-ended and non-restrictive as to time frame, proponents requested that there be a minimum guarantee period for the incentive. It was requested that the policy should permit payment of the incentive on any blend of ethanol, for example, to make it possible to boost octane in premium unleaded gasoline, which did not require something as high as a 10% ethanol component.

Subsequently, and just recently announced, the government has approved payment of the incentive in proportion to the percentage of ethanol in the blend, and has guaranteed the incentive to be paid for a

minimum of four years after production begins in an ethanol production facility.

Ongoing Developments

I might just mention some ongoing developments in the ethanol industry. I didn't write them into the paper because this changes quite quickly and I really don't want to say a whole lot about what the private sector is doing, because, you know, that's their business - some of them are here and you'll probably already have talked to them or will have a chance to talk to them about how things are going with them. But for example Northwest Food and Fuel is in the process of rebuilding their facility at Kerrobert and I understand that Paul Maker of Lanigan is in the final stages of lining up financing, and Paul Hill's Agroenergy at Belcarres are pulling together private and public financing. So I can't say when those are actually going to start, but those three are very far along in the process of lining up their financing. Actually, there's a fourth one, a group at Maidstone that I think is somewhere just about as far along in lining up their private, and they'll be needing public financing as well.

I didn't mention when I was going through some of the results of the studies, the indication was that there would be possibly room for marketing upwards of 50,000,000 litres of ethanol in Saskatchewan of these three plants, Northwest Food and Fuel is looking at production of 3,500,000 litres and the other ones are looking at a range of production of 10,000,000 litres. There certainly is room for those three, and according to the analysis, there will be room for others. Those three or four are the ones that are farthest along in feasibility studies and lining up financing.

So that is really the result of the programme to date. It is a changeable situation, but, nevertheless, under the programme, I think there's been real significant progress and yet it is complicated to get into something new, because, you know, it is really new. Maybe it seems fairly obvious to those of us who have been involved with it for a while, but for people that have been in other kinds of area enterprises to get into this kind of enterprising does require consideration, and I think it is certainly good that they are taking their time to analyze the situation. So sometimes we're asked is that as far as it's gone after as long as we've been looking at it or as long as the incentive programme has been in place, but I think it's good that they are taking their time and that it's being inspected, and you know, things do change - grain prices change and all prices change and so on, so that analysis is a continuing thing.

So that's the programme to date. I think that's fairly short, as I promised. I'll turn it back to you, Mr. Chairman.

FUEL ETHANOL POLICY AND DEVELOPMENTS IN QUEBEC

by

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Department of Agricultural Economics, Macdonald College of McGill University, Montreal, Quebec. Presented by L.B.B. Baker at the Canadian Power Alcohol Conference, Alcohol Fuels For Transportation, International Inn, Winnipeg, Manitoba, October 3, 1988.

INTRODUCTION

In this presentation, what I would like to do is outline the current situation in Quebec as regards alcohol fuels, particularly ethanol. First, I want to point out some of the reasons that Quebec could benefit from a fuel ethanol industry in the province. Next, I will say a few words about the state of the industry and I'll follow this with a discussion of current government policy and developments in the petroleum sector. I will also make a few comments regarding the state and direction of research in Quebec, and make reference to what we are doing at Macdonald College. Finally, I'll suggest where we might be going, especially in the area of policy, and why we can express some guarded optimism.

THE POTENTIAL FOR ALCOHOL FUEL PRODUCTION IN QUEBEC

Quebec is well known for its vast hydro-electric resources, and the government has been active during the past few months, trying to put in place additional capacity (beyond the current level of 22,000 megawatts) for increased exports to New England. In the area of oil for transportation fuels, Quebec is in an equally impressive deficit position, totally dependant on off-shore

supplies and crude from western Canada. Quebec is now importing 100 million barrels of oil per year with approximately 50% coming from off-shore. This makes Quebec particularly vulnerable to shocks in the world oil market. With the closing of four of the six refineries in Montreal, the province is now having to import the equivalent of about 25,000 barrels per day of gasoline which increases costs to consumers, and should provide some incentive for a fuel ethanol sector in the province. All this should make Quebec interested in alternative fuels.

If Quebec were to develop an alcohol sector, it does have excess resources based on biological feedstock to support it, so that the existence of the sector need not put any noticeable economic pressure on the production of other commodities. There are abundant forest wastes and low quality timber that could be used, and there are a number of fast growing species such as poplar, aspen, and willow that could be "farmed" on marginal agricultural land.

Quebec has a considerable reserve of about 1.55 million hectares of available, marginal agricultural lands (classes 4,5,6). Currently, these lands are of little use and exist as non-productive woodlands, or are used for rough grazing and rangelands. At present they provide little income to the farmers who own them. There are also lands in southern Quebec where the soil has been damaged by years of monoculture corn, for which suitable rotation crops are being sought. Some of these lands could be used for this type of enterprise. Not only is tree farming a possibility for

these lands, but there are a number of non-traditional field crops, such as Jerusalem artichoke, that show potential and could be grown as an ethanol feedstock.

In 1983, Quebec produced 247,000 tonnes of sugar beets under contract with the sugar refinery at Ste. Hillaire. This decreased to 130,000 tonnes by 1984 as the refinery slipped into bankruptcy, and political controversy. The refinery could be converted to an ethanol plant and the farmers could produce Jerusalem artichoke or other ethanol feedstocks instead of sugar beets.

Unlike western Canada and Ontario where the primary feedstock of interest has been grains, Quebec still is in a significantly deficit position for feed grains, so there is probably little scope for using grains as a feedstock. Beyond this, a considerable body of research in Canada and the US has concluded that the economic viability of ethanol production based on grains is questionable, even at their recent historically low prices. However, there has been almost no attempt to measure the non-market benefits of ethanol in meeting environmental, energy security, and agricultural goals, and these are viewed as positive and if quantified, could change the situation for grains, as could improvements in technology.

Thus, in Quebec the incentives and the resources on which to build an ethanol industry presently exist, and this new activity could help reduce the rate of unemployment which still stands at more than 10%. There are other petrochemical projects in the planning stages, but a fuel alcohol sector based on a locally

produced feedstock could have more significant impacts on the economy than for projects based on imported feedstocks.

THE CURRENT SITUATION OF THE ETHANOL SECTOR IN QUEBEC

The private sector in Quebec has been involved with fuel and industrial alcohol for many years although there are only a few companies that are active and no companies are currently committed to producing fuel ethanol. There is only one commercial scale producer of ethanol in the province, that being Commercial Alcohols Ltd. in Montreal.

This company has a long history of involvement in the production of ethanol dating back to 1923. At one time, they had two small plants using waste sulphite liquor from the forest industry in northern Quebec, but these are no longer in operation. In the late 1960's they opened their current production facility in Varennes, south of Montreal, which now has a capacity of about 70 million litres, making Commercial the largest ethanol producer in the country. However, they do not use biomass as a feedstock; instead they are using ethylene, supplied by Petromont, and they have been oriented toward the industrial rather than the fuel market.

Lately, the price of ethylene has increased to about 30 cents/pound US from about 13 cents early in 1987. With ethylene prices escalating, and with the longer term potential of permanently higher ethylene prices linked to higher oil prices, Commercial is interested in exploring other feedstocks. They have explored the

use of agricultural feed stocks, but at this time they have no definite plans to proceed in this direction, other than the use of crude alcohol from the EEC "wine lake" as a "stop-gap" measure. They would likely be a player if a significant fuel ethanol sector were to develop in Canada.

THE POLICY POSITION OF THE QUEBEC GOVERNMENT

Quite simply, everyone in the industry has the impression that the government of Quebec is not too interested in alcohol fuels. Throughout the recent past, it has not had a well articulated policy on alcohol fuels, and has done very little to promote the industry. This is reflected in the activities of the Quebec departments of energy and agriculture which have had some interest in alternative fuels, but have not actively pursued them. This attitude on the part of the government is understandable in view of their long involvement in the petrochemical industry, attempting to preserve what is left of the industrial base of east end Montreal.

The perception was also recently confirmed when on Sept. 14, 1988 Quebec's energy minister, John Ciaccia, released the province's long-term energy plan "Energy: Driving Force of Economic Development". There is nothing in the plan to encourage the alcohol fuels sector, as the report focuses on Hydro Quebec, the petroleum industry and hydrogen fuel.

In terms of current policy, Quebec has no tax exemption for alcohol fuels, as there is in most of the rest of the country, and

the Ministry of Energy does not appear to be considering any such exemption. Neither are there any special fiscal incentives for companies that might consider entering the market.

Apparently, the government does not see alcohol fuels as a factor in the near term, and appears to prefer that some other solution to the octane problem is found. Within the government, there seems to be a preference for the MTBE solution. However, there are persons within the department of energy who are sympathetic to the idea of an alcohol program. Thus, in the longer term, the government may be willing to consider the development of a fuel alcohol alternative, and to this end are supporting research and development to a limited extent, mainly in the area of utilizing forest biomass such as sawdust and wood chips. As such, they are following the lead of the federal department of Energy Mines and Resources which has indicated a preference for cellulosics which could be some time away from commercialization.

One of the vehicles through which this research may take place is Le Centre Quebecois de Valorisation de la Biomasse (CQVB). This is a government of Quebec corporation created in May 1985 to help promote research and development in the area of biomass. Their mandate has been to identify needs and determine priorities in the areas of biomass research and development and to assist the realization of projects through the provision of seed capital. One requirement of the CQVB is that an industrial partner is involved who could exploit the results of the project. Bioenergy has not been one of their focuses, although they have participated in

related research, and seem to be open to the idea of becoming more directly involved in ethanol related research projects.

Within MAPAQ, the Quebec Ministry of Agriculture, there is very little work being done by in terms of bioenergy research. However, they appear to be becoming more interested in fuel ethanol and are involved in a recently formed coordinating committee involving the Quebec energy department, the Union des Producteurs Agricoles (UPA) and some academics. This committee has been developed to share information, develop priorities, and investigate the area of bioenergy from agricultural sources. These would include grains, agricultural wastes such as whey, and various manures. The involvement of the UPA in itself is a positive sign for the industry, since if they come to believe that it is in the interest of farmers for an ethanol sector to develop in Quebec, they will be able to generate significant political pressure.

PETROMONT AND THE SOLIGAZ PROJECT

One of the most important factors related to the future of ethanol in Quebec relates to Petromont and its proposed Soligaz project. Petromont is a limited partnership of the Quebec government, through Le Groupe SGF (Societe generale de financement), and Union Carbide of Canada. In recent years it has received $225 Million in assistance from the federal and provincial governments. Its main products are ethylene and propylene, based on naphtha derived from imported crude or propane and butane.

Petromont is interested in obtaining a less costly supply of

natural gas feedstocks and are promoting the construction of a natural gas liquids pipeline from Sarnia to Montreal, the so-called Soligaz project. They are participating in the proposal with Noverco Inc., SNC Group, and Soquip, (Societe quebecoise d'initiatives petrolieres) Quebec's oil and gas agency. The project is reported to be worth up to $300 Million and the company claims that it will stimulate additional investments in the Montreal area of about $1.5 Billion. The proposal involves a doubling of Petromont's capacity and a market reorientation towards the North-eastern United States.

There are two aspects of the project that are worrying for the future of the development of alcohol fuels in Quebec. First, as a result of the potential availability of cheaper natural gas liquids, there is a proposal to build a $200 Million MTBE plant which would have enough capacity to practically eliminate the need for other octane enhancers in Quebec. Second, Andre Lapalme, the president of Petromont, has indicated that the company plans to market propane as an alternative fuel. It has been reported that the government is considering an exemption of the 9 cent/litre sales tax on propane fuel, which if implemented, could seriously affect the argument for a fuel ethanol sector in Quebec.

Although the Soligaz project is not a certainty, the heavy involvement of the government of Quebec suggests that the project is a very likely event. A decision is expected sometime in the fall (probably after the election call).

CURRENT RESEARCH AND DEVELOPMENT EFFORTS

Although the climate created by the government has not been encouraging, there continues to be a modest research and development effort on the part of private industry and the universities.

The company with the most active research and development effort related to ethanol is Techtrol Ltd. of Montreal, under the direction of Mr. Pat Foody, who has been working in the area since the early 1970's. At present, much of Techtrol's research effort is carried out through their subsidiary, Iogen in Ottawa. Techtrol's research is primarily oriented towards developing the technology to refine biomass into products that could be used by the chemical industry. Forest or agricultural biomass such as wood chips, willow, Jerusalem artichoke, or other field crops or wastes are pretreated to yield cellulose and six carbon sugars, lignin, and hemicellulose. The cellulose is hydrolyzed and the sugars are either fermented, dehydrogenated or hydrogenated to yield a range of products including ethanol. The ethanol could go directly to a fuel market or it and the other products could be further processed into a wide range of industrial chemicals, plastics or drugs. Likewise, the hemicellulose and lignins could be processed into many different products.

Although their primary interest is not ethanol, much of the research and development they have done in the area of the enzymatic hydrolysis of cellulose has had a direct effect of advancing ethanol technology and reducing the cost of producing ethanol from cellulosic biomass.

Their work has taken them into areas of co-operation with other companies in Quebec and they have also co-operated at various times with researchers at the University of Toronto and Macdonald College of McGill University. We anticipate that the co-operation between Techtrol and Macdonald will be expanded where we see mutual interests in the area of agriculture.

In Temiskaming, Tembec has been involved in trying to develop a commercial scale plant for some time. They have plans to build a plant for alcohol using available sources of spent sulphite liquor from the local pulp industry. No starting date for a plant has been announced and they have encountered some problems since the pulp mill has recently switched from using soft woods to using hard woods, which are harder to break down for fermentation. They are working on a yeast that will handle the hard woods. They feel that they are ready now economically to use soft wood residues but not hard wood residues. Tembec would produce a very small amount of alcohol if and when they solve the hard wood problems.

During the past few years, the Quebec energy department has been supporting a number of research efforts through their Division des Energies Nouvelles. They have been supporting the work of Dr. Anh Leduy at the University of Laval who has been working in the area of enzymatic hydrolysis of forest biomass. The energy department also supported for some time, pre-feasibility work at Mont Laurier, in the Laurentians, aimed at developing a plant based on saw-dust and wood chips using acid hydrolysis, but the economics were not encouraging and the study never proceeded to the feasibil-

ity stage.

Another project that has been ongoing for about ten years, with their support, and the federal department of Energy Mines and Resources, is the Biosyn plant in southern Quebec. The plant has been using technology purchased from CIL to produce methanol, but has had trouble producing up to specifications. Recently, there has been an attempt to improve the situation with the participation of CQVB. They are focusing on studies looking at using forest and municipal wastes in the production of methanol.

An important centre of research related to ethanol production is at the University of Sherbrooke under the direction of Dr. Estaban Chornet. Dr. Chornet's lab is known as LALM (Le Laboratoire Associe/ Materiaux Lignocellulosiques) and was the first lab put in place with the help of the CQVB in 1986. Generally they have done considerable work on starch materials and have patented a process for hydrolysing starch into sugars. At present, their work is focused on the evaluation of residual lignocellulosics derived from agriculture and the forest industry. These are evaluated using a Stake II steam explosion unit for pretreatment and a continuous acid hydrolysis unit that they have developed. They are evaluating the derivatives of these processes that could find applications in industrial chemistry, as co-products to ethanol, thus improving the economics of alcohol production. In addition to the support provided by the CQVB, the LAML has also received support from the provincial and federal departments of energy, NSERC, NRC, and private industrial partners.

In the Department of Agricultural Economics at Macdonald College, research on ethanol began in the early 1980's, when several researchers (L.A. Fischer, M. Churches, H.G. Coffin) were involved in a study of the ethanol industry, "Economics of Fuel Alcohol Production in Eastern Canada, 1982". The research at the time addressed the questions of fuel demand and supply, our national energy policy, and various alternatives for the production of fuel ethanol from biological feedstock. At the time, the investigation was addressing the possibility of using ethanol as a fuel extender. They also investigated the production costs of fuel alcohol using comparative data from 29 US plants. The final results indicated that Jerusalem artichoke was the most feasible feedstock while also taking into account plant scale effects.

Our current research is investigating ethanol for its potential as an octane enhancer with minimal environmental impacts. Using an agricultural feedstock for the production of ethanol is viewed as a means of diversifying agricultural production and increasing agricultural income. The work to be conducted will address the questions of whether ethanol production is economically feasible from an agricultural feedstock and the potential macro-economic impacts of the development of such a sector on the Canadian economy. This approach has been taken in order to (1) indicate to the private sector that such a process is feasible and (2) provide information to decision makers in government of the potential benefits in terms of industrial output, employment and Gross Domestic Product (at factor cost) of such an industry.

Encouraging results will hopefully provide an incentive to develop government policy to support such an industry.

Thus far, our attention has been focused on Jerusalem Artichoke as a potential feedstock. There are several reasons for concentrating on Jerusalem Artichoke: yield of ethanol as compared to other agricultural crops, the use of Jerusalem Artichoke in rotation in areas where monoculture corn is common, low management requirements, and its suitability to marginal lands.

Jerusalem Artichoke tubers as compared to sugar beet, corn and wheat, yields 1.7, 2.0 and 3.7 times more alcohol on a per hectare basis respectively. Jerusalem Artichoke produces abundant top growth, dependant on variety, which also can be used as an ethanol feedstock. Yields up to 80 tonnes per hectare of top growth have been reported in field trials at the Agriculture Canada research station at St. Jean, Quebec. Focusing on the top growth could allow for a lower cost of production in terms of planting and harvesting, and less soil degradation than if Jerusalem Artichoke tubers are used. The cultivation of Jerusalem Artichoke tops might be appropriate in regions of southern Quebec which are looking for alternative crops which can be used in rotation with corn. Finally, Jerusalem Artichoke is reported to grow well on marginal lands, and Quebec has such a potential land base. This could provide agricultural producers with a higher return than present opportunities for these lands.

We have conducted a preliminary analysis to examine the macroeconomic impact on Canada of an ethanol industry based on

Jerusalem Artichoke, assuming that approximately 900 million litres of ethanol would be required. We also assumed that all gasoline in Canada was a 5% methanol and 3% ethanol blend. This blend would also require the production of 1.5 billion litres of methanol.

The tentative results of our investigation indicate that the cost of producing Jerusalem Artichoke would be $16.00 per tonne which would result in a net cost of ethanol of 33 cents per litre, assuming the ethanol was being produced in a 100 million litre plant. The macroeconomic impact of such an industry on the economy, in terms of direct, indirect and induced effects are an increase in industrial output of $1.95 billion, an increase of 16,767 jobs and an increase of Gross Domestic Product at factor cost of $770.4 million. These results were estimated using a modified version of the 1984 Statistics Canada Medium Level Input-Output Model. These preliminary results are seen as being important in terms of information required by decision makers.

We have recently received funding from the Canada-Quebec Entente to refine our methodology and to apply it to Quebec. If the economics of such an industry are shown to be feasible, we will pursue additional funding to undertake a much larger interdisciplinary study which would include such things as: production field trials, co-product valuation, pilot plant research, consumer acceptance of a blended fuel, industrial organization work in terms of adjustments needed by the petroleum industry, and consumer valuation of the environmental benefits.

CURRENT AND FUTURE DEVELOPMENTS IN POLICY AND RESEARCH

While the past policy environment has been somewhat discouraging, there are still some reasons to be optimistic that an ethanol industry could develop in Quebec.

On Sept.9, 1988, Marcel Masse was in Varennes, just south of Montreal, to open a new laboratory for the Canadian Centre for Mineral and Energy Technology (CANMET). It will have a budget of about $3 Million/year and part of the focus of the lab will be in the area of biomass fuels. How much of the budget will be fuel related remains to be seen. But, it has been reported that this laboratory has been located in Quebec in order to increase Quebec's share of EMR's R&D expenditures in the province, and if this is the case, it provides some encouragement that R&D on alcohol fuels in Quebec may get some additional support.

One thing the ethanol industry has lacked in its lobbying effort in Quebec is a significant political ally, while it faces significant opponents in the petrochemical industry. This ally may be found in agriculture at the farm level. If it could be shown that ethanol could provide significant benefits to agriculture in the province, farmers would likely support it and express their support through the UPA. The UPA is probably one of the best organized farm lobby groups in the country and has been quite successful at articulating the desires of its constituency and generating action from government.

Support from agriculture could be quite beneficial in another important respect. Even if there was a commitment to produce fuel

alcohols, they must be marketed and the fuel industry has not shown much enthusiasm in this respect. If the farm sector could be interested in fuel alcohol, Cooperative Federee the largest agricultural co-operative, might be interested in marketing the product through their independent network of Sonic gas stations.

In the policy area, even with the cool attitude of the provincial government, there is a perception expressed by some that Quebec, like some other provinces, is waiting for the federal government to develop a national program. If it looks interesting, the Quebec government would participate. Although there has been no direct indication that a tax exemption for alcohol fuels is forthcoming, the fact that an exemption for propane fuel is being considered leads one to suppose that perhaps they could extend the sales tax exemption to alcohol fuels.

With public concern over pollution recently heightened by the fire at Ste. Basile la Grande, there are two environment considerations that could help create pressures in favour of fuel alcohols. First, concerns over pollution from the pulp and paper industry could lead to actions by the government that would make further processing of wastes into alcohols look more attractive.

Second, as is well known, in 1986 Environment Canada announced new lead emission standards for vehicles, and plans to effectively eliminate, by December 1992, the use of lead. Recently, the federal government pushed its deadline for the elimination of lead to 1990. In response, refiners have been increasing the operating intensity of their refinery processing to achieve sufficient volumes of high

octane fuel components and, in addition to the increased costs involved, this is leading to the production of gasoline containing more aromatics, such as benzene, xylene, and toluene. With the recent passage of Bill C-72 (the Canadian Environment Protection Act) we could expect that the public may reject the refiner's solution. The industry's other solution MTBE, is also questionable due to mounting evidence on its mutagenic and carcinogenic effects.

Finally, if government were to provide some incentives to industry, it appears that there are already firms with sufficient interest to make the size of investments required to launch an ethanol sector.

OXYGENATED FUELS IN ONTARIO

by

MR. BARRY BEALE
ONTARIO MINISTRY OF ENERGY
TORONTO, ONTARIO

Taking the last session of the day is always a challenge. I don't know if you found the chairs as hard on you as they were on me - if they have been you'll note I take some comfort in knowing that regardless of what I say, you're going to be sitting on the edge of your seat, or at least moving around a little bit.

I look around the room and I'm reminded of one of the things that Michelle Heath mentioned today, and that is what is going to make this industry work is for co-operative efforts of an awful lot of people and an awful lot of industry. A lot of the people in this room do have some conflicting interests in oxygenated fuels and I suspect you also have some conflicting views on whether oxygenated fuels are really opportunities or, as someone in the oil industry once termed them, a pain in the gas.

I'd like to take a look at some of those conflicting interests, just briefly, just to set up some observations I have on Ontario's perspective. The fact that this conflicting interest isn't a big deal in terms of setting policy, it happens all the time. Oxygenated gasolines, in particular though, cover a broader spectrum of interest in far greater depth than most public policy issues. We have agriculture interests, farm incomes are important and rightfully so; new markets for agricultural products - these are important. We have entrepreneurs among you who are looking to make investments, perhaps in ethanol facilities. Regional development is important in every region of Canada - no less so in Ontario. Jobs are important. We have conventional fuel suppliers, refiners. Once you pass all the marketing hype, gasoline when graded is basically a very undifferentiated product - gasoline marketers live and die on quality, consistent quality, and, at least in some places in Toronto, I'm told, they'll kill for half a cent a litre. So price is important. The vehicle manufacturers who, one can understand, get a little concerned when people start talking about putting new things into their vehicles, that the vehicles were not built for, which may or may not improve the performance of those vehicles and the satisfaction of the customers. And we have the research community, who are always looking for new and better ways of improving the science and the technology to make product costs lower, and to make the products better themselves.

Now this may come as a surprise to some of you who are not too familiar with the workings of government, each one of those interest groups is a client somewhere in the government. Some department in the government looks upon those groups and says, I'm going to take care of those people - these people are those interests that I'm responsible for. It's important to recognize that, because as soon as you do you understand some of the things that Tony Taylor was talking about, and as well, the composition of

the commission in Alberta. Every one of the departments, environment, agriculture, energy certainly, and industry, trade and technology in Ontario, have an interest in ethanol. When I have any substantive discussion about ethanol or oxygenated gasoline, the first thing I have to do is, how do you think the government handles that, have a meeting. And who do I have a meeting with? I have meetings with agriculture, environment, three divisions of my own ministry, industry, trade and technology deal with the regional development issues, and I ask people from the Treasury to come over because they hold the money and their influence is important, and transportation.

I guess the message is that at this point in oxygenated gasoline development, the Ontario Government generally has an interest, but at the price tags that we've been offered to develop this industry, there's no champion. And that's as true for energy as it is true for agriculture, and I don't want to speak for agriculture although I may privately.

The kind of numbers that Michelle Heath was referring to this morning, in my view right now, under the environment that we as a ministry are creating, are too high. And certainly some of the projects sponsors that have come to us for funding in the past have come to us with projects which do not help your industry - do not help this industry to come through and have discussed with the cabinet projects that require a 100% capital funding and 20¢ a litre on top. So right now, unfortunately, in Ontario, the situation is that there's no chance. We do have an interest.

I think it's important though to understand that Ontario has been in the past the most aggressive, or at least among the most aggressive jurisdictions in North America in promoting alternative transportation fuels. The roots of our interest go back to the late 70's, early 80's, when oil prices were expected to increase to $60-$70 a barrel by now. Not only was oil going to be very expensive, it was going to be not in secure supply. In that environment, the federal government decided that a fairly substantial intervention into energy markets was appropriate, and they introduced the National Energy Programme, and emphasized very heavily energy self-sufficiency, and oil substitution. And Ontario followed that line, we were operating in the same environment, and we aggresively moved into alternative transportation fuels. We offered fiscal support, fuel tax relief, capital grants, research and development - we looked long and hard at our entire regulations, regulatory base or legislative base and cleaned those up as best we could. And in the end, we spent, as a ministry of energy, we've spent several millions of dollars in promoting alternative fuels, including oxygenated gasoline, doing research, doing demonstrations, and the Ontario Government has spent, if you count tax not collected as spending it, well over $200,000,000 in supporting, not this particular industry, but the industry of alternative fuels generally.

The environment that we're working in right now is quite different from that environment where it was urgent that we do something and programme planners and policy developers were virtually working under crisis conditions. Oil prices have fallen, all energy prices have fallen. Supply concerns are not as big a problem, in our view, as they were a decade ago. And if I had to, I guess, just in very few words, describe what our planning outlook is, what we see on the horizon to the year 2000,

I'd say that in the transportation fuel market we expect our needs to increase by about 25%. Transportation remains almost 100% dependent on crude oil, and the oil products. We expect energy prices to increase modestly over all, but we also expect that those increases will be spiked by periods of intense volatility, both up and down. But on balance, modest increases. We also expect that energy supply availabilities will, on balance, be reasonably secure, with the possibility of some short term disruptions in supply. These are conditions which are quite different from the late 70's, and force us to re-examine all of our programme activities and virtually all of our policy pronouncements as well.

In that kind of context though, we start to see how it is that we might be viewing, not just oxygenated fuels, but most transportation fuels - auto propane and natural gas for fuels. We are, and remain committed to inducing structural change in the way transportation energy is used in Ontario. And we think we can achieve that structural change by moving as best we can towards increased fuel efficiency and through the introduction of new transportation fuels, creating energy choices for Ontario transportation fuel consumers. This is something we want to do. But we want to do it in a timely way, and we want to make sure that the efforts that we make have a durable contribution.

Barring any significant or unanticipated strategic rationale, any new fuel, whether it be oxygenated gasoline or automotive propane, and most of the new technologies that are becoming available even for improving energy efficiency and the way we use energy in our industry and in our homes, has to accommodate, or at least recognize, that we are in a period of energy markets where conventional fuels are abundant, well priced, and we have some supply surety. New fuels have to be introduced, recognizing that these markets are going to be volatile and to be successful and durable, these fuels have to be capable of being competitive when energy prices are low, not just when energy prices are high.

The ministry has spent a great deal of time, staff time, it's spent a great deal scarce resources supporting the development of the greater understanding about oxygenated gasoline. We have co-funded many research programmes on improving the production basis for producing ethanol, for example. We have undertaken I don't know how many - I would say probably half a dozen different vehicle trials, using different blend formulations, in sponsorship with the private sector. And we've tried to disseminate that knowledge as widely as we can. I think we've come to a point in this planning environment, right now, where we believe that the private sector has enough information to judge both the timing and the commercial attractiveness of alcohol blends. And for those that view the market favourably, and some in Ontario do, you'll be hearing tomorrow from V Plus who have a number of stations selling methanol blends, United Cooperatives of Ontario that are doing market trials right now. There's an ethanol plant under construction in Bruce Industrial Park. For those that do find alcohol blends to be an attractive investment opportunity right now, under these conditions, or ten years from now, we ask only one thing - we ask that that fuel comply with some minimum quality standards, and we are suggesting that the Canadian General Standards Board is the most reasonable place to develop that quality standard. It is in nobody's interest in this room to have extreme variation in quality in the marketplace as this infant

industry grows. And we feel very strongly that the issues to deal with utilization of these fuels have to be settled in a forum such as the Canadian General Standards Board. Now I understand that that Board has a ballot right now that's out for vote on just that standard So I'm hopeful that the industry will be able to move forward knowing the kind of product that is going to be out in the street. So that we all have a better feel for what the opportunity for ethanol production is, what the blending requirements are going to be, so that we all understand what it is and everybody is working on a level plain.

That process is very important, so that different interests, as there are here, can come forward, argue on the technical merits of their position, and have it resolved. It sometimes takes longer to resolve than at other times, but the process is very important - let everybody get a shot - and that a concensus is reached. We require minimum quality standards in Ontario, not because we are particularly nasty, it just happens to be in legislation that was drafted over the years.

I mentioned that Ontario does offer fuel tax support - a preference on fuel tax - towards oxygenated gasoline. Right now the value of that support is worth about 20% or more of the product price for oxygenated blend stock. Under the planning environment that I just described, we think that that's enough right now. We'll entertain project proposals from people who want to build ethanol plants and we will review them and we will make our recommendations based on the merit of the cases.

The last thing that I would like to say is to echo a few things that I've heard. We think that the federal government has to stand up and take some control over the development of this market. My concern is that if we don't, there will no doubt be a whole bunch of little regional markets scattered around this country based on one kind of blend, based on product manufacturer as in Saskatchewan, based on the particular views of whatever finance minister happens to be in that portfolio in that province in any particular year. That does not strike me as a way to build a durable self-sustaining industry. Transportation fuel industry in this country generally deals in national logistical problems and until oxygenated gasolines have an opportunity of participating nationally, I don't really believe that the long-term future of ethanol is going to be a particularly astounding one.

Having said all that, I'm cautiously optimistic that this new industry will grow, but it's going to take, in Ontario, for those of you who are interested working in Ontario, it's going to take a champion, it's going to take the appropriate pricing and technology conditions, and it's going to take some leadership from the federal government.

Thank you.

Ben Henneke Jr., President, Energy Fuels Development Corporation. Portales, New Mexico.

Ben received his Bachelors degree in history in 1968 from Yale University and an M.B.A. from Harvard Business School in 1973. He has been involved in the coal and ethanol industry for the past fourteen years. In 1974, he organized a coal reclamation company and in 1975, joined ICM Corporation as vice-president and chief operating officer responsible for evaluation of proposed company acquisitions. In 1977, he founded Arkoma Coal Corporation. In 1982 he founded Energy Fuels Development Corporation which has constructed a $30 million ethanol plant in New Mexico.

NOTES FOR SPEECH TO THE
1988 CANADIAN POWER ALCOHOL CONFERENCE

by

MR. BEN HENNEKE
PRESIDENT, ENERGY FUELS DEVELOPMENT CORP.
PORTALES, NEW MEXICO

Henry Kissinger used to record all his speeches in an effort to make sure that he didn't get misquoted. I'm doing this because I could not convince my wife to come and listen to what would happen when I had the opportunity to take on a topic as broad and as wonderful as oxygenated fuels in the United States. I was reminded as Ted gave that very nice introduction, of the difference between an introduction to a speech and a eulogy at the funeral. An introduction to a speech, in other words, at least one person who believes what the person, the man speaking is saying. At the funeral, there's generally no one there.

You know, you're required to tell a joke at the beginning of a speech, and I've never been very good at that. It's been one of the tough things about making speeches for me, because you're supposed to help warm up the audience, you're supposed to get them in the mood. They've had a nice dinner, and they're sitting back comfortably on those wonderful chairs that we all enjoyed all afternoon, and thinking about how much they'd rather be somewhere else, since now that dinner's over, couldn't they get out of here. But I'm going to have to say that this is an important issue, and I'm going to spend a few minutes discussing it; but I'd first like to talk to you about a gentleman who I did not meet. I was unlucky enough not to get to meet him, but he lives just south of here in a town close to Cass Lake, Minnesota, down by Bemidji, and he had an important thing to say to all of us about the ethanol industry, about oxygenated fuels, about alternative fuels, about clean fuels - whatever we want to call the various things we're talking about today. One morning he decided he would go out and go ice fishing. He just suddenly had the urge. So he took his equipment, got warmly dressed, a nice saw, and he went out and arrived, chose a nice piece of ice and started sawing. And he was sawing and sawing and sawing and sawing and sawing, and the ice was very thick and very hard. And he was sawing and sawing, and suddenly he heard a voice. "There are no fish under the ice." He looked around - he couldn't see anybody. He looked around again and couldn't see anybody. So he went back to sawing. And he sawed and he sawed and he sawed and he sawed and he sawed, and again the voice came, "There are no fish under the ice." He looked around again. Nobody. So finally he went back to sawing again. And the voice came again a third time, "There are no fish under the ice." He looked up and he said, "Lord, Lord, are You talking to me?" "No, this is the skating rink manager. There are no fish."

Well, you know, when oil prices are on their way down to $12, and grain prices are up and up and up again, and a lot of us, like myself, who have been in the alternative fuel business since '73 and in the ethanol industry, on and off, since '80, you begin to wonder if there are any fish under the ice. At what point are we going to get back to the point where

we get our fishing rods out and we get to go and catch a few, instead of just sitting and sawing and sawing and sawing. Well, you are very lucky, you're twice blessed, I think, as far as I'm concerned at least, because, I mean are you aware of how lucky you are to have Art Meyer to come and speak to you at lunch - are you really aware how wonderful that speech was and what a great man he is and all those terrific things. We are twice blessed because Art said most of what I'd prepared to say and, therefore, you can take the ten minutes that he took for his luncheon speech and deduct it from mine, and we'll all be a lot better off. But, how many of you do not remember the luncheon speech and, therefore, I have to kind of do a summary for you. Oh dear! Well, we have one hand raised - the rest of you are in trouble now.

Let's go through real quickly what I think is an important kind of recap on the ethanol industry, and I'm going to remind you of a fairly famous wag from your mother country, and ours, who stated that the only thing that separated the United States and Great Britain was their common language. And so, I'm going to do the best I can by taking Winston Churchill's advice, and I'm going to translate to Canadian cents per litre the best I can, but if I get tongue-tied or confused, I'm going to go back to American dollars per gallon because we're now separated not only by our common language but also by two different sets of measurements which make no sense at all. If we had both gone to dollars per litre, or if we'd even decided to keep our currencies locked together, or if any of those things were useful, we could have a little better dialogue. But I went through most of the discussion this morning trying to follow things and trying to convert in my head and it was only two-thirds the way through that I realized we were talking Canadian dollars, as well as litres, and I'd only been converting for litres.

Real quickly. Energy Fuel, the company that I'm President of, built without any Federal guarantee, a 10M gallon/40M litre ethanol production plant in New Mexico. Now, we'd managed to get bank financing for that. It should not have been built - I will introduce you to my banker if you have any questions about whether or not it should have been built. It was, it turns out, and I realize that somewhere after we got the financing closed, that it had been impossible. But I had, for three years, been so stupid about the fact that it was impossible that I didn't notice and I fooled some bankers into suddenly kind of catching the spirit and all of a sudden we had a financial closing going on, and we've all been very sorry about it ever since. This is a real case of being careful what you pray for. I hear about the people wanting to build 5M and 7M and 10M litre plants in various places and my recommendation is, you know, draw back while there's still time. It is a very unpleasant experience to get to own an ethanol plant and within four months of start-up be locked out by the oil companies from having any source of lending. You know, we talk about ethanol as a fuel, but when it is 10% ethanol and 90% gasoline and if you can't get or buy the gasoline - you know, you don't have a business. And we went in twenty-four hours from being sold out, to having no sales - April 16th, 1986 - I remember it very clearly.

Since then, we've had the opportunity - of course, we got started up December 18th, 1985 - oil prices fell to a third of their previous amount within thirty days of start-up. We then had a little period of time

when as we began to get production up and sales up - things were going along pretty well - then we discovered that the dryer in our plant - $26M in the contract - American - so call it 30 what 3? Is that close? 33M for 40M litres, but we've now got it up to where it's about 50, so you divide that out any way you want to - but it has full carbon dioxide units, it has full grain drying, it has coal-fired boilers as well as the gas-fired boilers - in other words, a pretty complete plant. That particular plant we discovered was complete in one other respect in that it had a carbon steel dryer and a highly acidic environment, and therefore, we had a new cooling device for our distillers dried grain, the dryer perforated on the shell and brought in additional air to kind of act as a cooling device. That was good because our cooler was also made of carbon steel and it perforated and started squirting water everywhere - it was a water cooler!

Are you sure any of you want to do this? Well, you've heard it all. You've heard it from Art, you've heard it from other speakers, and I really would like not to repeat it too often. But, let's go through it real quickly - why is it we're so wonderful. We're so wonderful because we're renewable, we're so wonderful because we're domestic, we're so wonderful because of rural jobs, we're so wonderful because we're upgrading raw materials - there was a wonderful little war in the United States, back in the Colonials called the Whiskey Rebellion, and that was because corn growers wanted to upgrade their product and reduce the transportation cost by turning it into hooch - and we're basically, you know, doing the same thing, 200 years later. We're wonderful because of carbon monoxide reductions, we're wonderful because of carbon dioxide reductions - gosh, we didn't even think about it until six months ago and now we're famous because of the Greenhouse Effect. We've got lots and lots of wonderful future because we're learning, the learning curve, whatever you want to call it - whether you want to call it profits improvement, and I understand that just before I got here there was a wonderful talk from the Mohawk guys about how, you know, the operators figure out how to make it run even though the engineers can't - and they do! You know, slowly but surely the operators make it run better and better and better and better and finally have the experience and money to de-bottleneck it somewhere else because they've done things that you can't get, that you couldn't have figured out yourself.

So we've got all these wonderful things, and it is kind of like being in a 1930's refinery - you walk through one of our plants and you look at how much they've changed - I built a first generation plant in 1980-81, second generation plant in '85-86, rebuilt the second generation plant in '86-87, rebuilt the second generation plant in '87-88, and now I've got either a first or a fifth generation - your choice - plant operating, and we all know we're in a 1930's equivalent technology. In 1930 how many products did a refinery make? Anybody? I don't think we're old enough. Anybody remember? That's how many products came out of a refinery in 1930. Our dry mill produces three products; carbon dioxide, distillers dried grain, ethanol. Yet I know inside that distillers dried grains are a whole bunch of interesting protein isolates, a whole bunch of interesting chemicals I don't know how to get them. I don't know how to separate them yet, but I know they're there. The refinery didn't realize that they had MTBE - they didn't know about ethylene - there are a whole

bunch of things they didn't know in 1930 and they do today. So, there's all that great stuff going on but it's interesting, and it works so darn good. Why is it so hard? Why is our life so miserable on a day in day out basis?

Why is it none of us make money? Well, now maybe Mohawk does, and I don't want to suggest they won't, and maybe the folks at Saskatchewan by being generous and, I think forward looking, will make some other people make money - I certainly hope so. But the reason it's not much fun and the reason if we're so good, things aren't going very well, is we're actually trying to interfere with two of the largest industries in the world, and that's petroleum and auto. And those are both entrenched industries, they're affected by us and they're entrenched, large, major bureaucratic industries with enormous contacts among each other, at all kinds of levels, for seventy-five years. And you have an upstart industry who wants to play the game differently and doesn't catch up to them. How many of you who are really interested in promoting ethanol, methanol, MTBE's or any of those have gone and called on the auto industry this week? Monday afternoon, Monday evening. Last week? How many of you other than Mohawk have spent time talking to another oil company that's not involved? Last week? The week before? This year? Well, the American industry has been famous for only talking to the oil industry when they were in Washington at a hearing, and typically they were not very civil when they did that because they were both in after their own benefit at that moment.

U.S. industry has lacked the leadership which understood that they needed to advertise in the Oil & Gas Journal, that they needed to have Hospitality Suites at national petroleum refiners, associations, at API, that you needed to recognize that you were an additive to the oil industry, and that you are an irritant to the auto industry, through your volatility, you sure as hell needed to be in there talking to them. We've also had the great advantage of having refining and downstream margins of retail go to historically high levels in the last two years - that always helps if you're trying to substitute your product for 10% of their product - their last, most profitable incremental barrels. It's not easy to make friends with a refinery manager when you tell him you're going to take away his most profitable barrels. Well, I'm told it is easy - I have never succeeded. And in fact, for the U.S. industry the success in Washington has actually become part of our problem.

The American Petroleum Institute, the motor vehicle manufacturers, they've pretty much had their way with Congress for the last forty years - certainly since 1950 when we began to take Federal monies and put them into Federal roads at an increasing rate which became in the '60's, the Interstate Road Program - the only thing, I understand, that you can see from the spaceships is the Interstate Road System and the ones that the Romans built two thousand years ago - the Romans' are still in shape, the Interstate System is actually in worse shape than most of the Roman roads. But that Interstate Road System and that backlash that we are getting is a very interesting thing - I think that our mistake has been that we have been talking to ourselves, and I think that you all today are making that same mistake. I see someone from Chrysler, and Chrysler has been one of the most difficult to read. Vehicle manufacturers, they will come and say nice things to your face and say nasty things on tape to other people.

Chrysler has been very confused - they had problems with materials compatability, they had problems with their own engineering, but they share these problems with other vehicle manufacturers. But that dialogue is not a two-way dialogue. No one has ever gotten through to any of the Detroit motor vehicle manufacturers that there was a benefit in finally getting the focus off of the American, and therefore Canadian automobile and onto the American refinery. For the last fifteen years, America has decided to play around with their cars as a way to clean up air pollution, and the brunt has been borne by the people who have to design, sell and then warrant those automobiles and they were being forced to move technology faster than they thought they could; they got stuck with a whole bunch of problems, and in between the refiners increased volatility, increased their aromatics, which of course have more materials compatability problems than anyone is willing to talk about, and surprise, surprise, the automakers take the hit again. Now, you know, you look at Brazil and it's just the opposite. They decided to leave the automakers alone because Ford Brazil and Volkswagen Brazil, and so on, had some strokes and Petrobras did not, because it was a government owned oil company - and so they did it just the opposite - they completely switched fuels and left the automobiles alone. Surprisingly enough, neither one is sufficient for the severity of the environmental problem.

Well, I think the backlash can be best seen in a very simple way. Let me tell you about a meeting I went to ten days ago, two weeks ago, and I was the only ethanol person there. I managed to get myself elected to the Highway Users Conference to the Board of New Mexico. Talk about the fox in a henhouse, except that in this particular case, it's a teeny-weeny fox with enormous hens all around. The Highway Users Conference - I was pretty awed by the kind of people who were involved just in Colorado and places like that, but I went up to Washington to the National Conference. The President of Operations of Chrysler gave the incredibly boring speech about their plans for the following year; the Executive Vice-President of Ford, who got elected as President the next year; the Senior Vice-President of Phillips got elected to a committee; the President of Amoco got taken off the Board because he had been on it for ten years. Well, the President of Firestone was there serving on a committee. We had the head of the Highway Contractors. We had Triple A's head, and what I didn't catch on to until half way through was that the group of men, all men unfortunately, but men sitting in the centre of that room who were the voting directors, I finally got a hold of a piece of paper that listed them, well, gosh, it turned out that the Director, I mean the President of Operations from Chrysler had his boss sitting as one of the Directors. The Executive Vice-President of Ford for Finance had his boss, the President of Ford, sitting as a Director. Amoco - it was the President. Firestone's President! Goodyear's President! Mobil's President! It was a pretty impressive group. And you look around and you say, 'Wait a minute. This is the Highway Users. These are the people who their first priority is to get the Highway Trust Fund reauthorized; their second priority is to make sure that the U.S. Congress doesn't put a penny, or ten pennies, or a dollar's worth of gas tax to try to balance their budget; and their third priority is to get rid of the gasohol exemption.

This fox felt very, very, very small in that henhouse. Those guys aren't chickens, those are eagles that we're talking about. There

were some very big eagles in there. There were twenty of them sitting over there, and they, as a group, are talking among each other. You know, what does the President of Ford know what is going on in gasohol? What does the President of General Motors know about gasohol? Nothing. Why should they - it's very unimportant. But they sit at a meeting where their third national priority is to get rid of us? Of course, they've got a negative attitude. Does that attitude trickle down to people in technical jobs? Does that trickle down to motor vehicle manufacturers, association; does that trickle down in a whole bunch of other ways? You bet. You bet. And so they sit there and they talk among themselves and they're just as blind as the ethanol and the alternative fuels people are. They sat and talked among themselves about how they were going to get rid of the gasohol exemption, and I have to admit, I gave real credit to the guy from Chrysler. He looked up from his prepared speech and said, "and with all the concern about the environment and all the concern about carbon-based fuels, this may (meaning getting rid of the gasohol exemption) be the toughest thing on our legislative agenda". Now, I would think a $12 billion a year trust fund would be a tougher job, but it obviously is not.

Why is it so hard? Well, we've lost that ability as a group here in Canada - you can't get your Federal Government to move and your Federal Government, I remember five years ago, was equally advanced as they are today - is that fair? You can't get your numbers right - I've just told you what our plant cost and all your discussions here today are at higher cost than at what we built it for. Now you might not want to have a carbon steel dryer - in fact, I would recommend if you want a good one - we'll give you ours - but there wasn't much wrong with our plant, and yet you're still talking as if it were (a) new technology and (b) as if it were more expensive than it is. So we need to go ahead and start talking among ourselves intelligently and passing accurate information back and forth, and we second, need to get out of here and start talking to some other people. I would suggest that since the major oil companies have decided to increase their retail, that you need to be talking to majors, because it's been less noticeable up here on this side of the border, I realize, but down South more and more of the convenience stores are becoming major branded, and fewer and fewer are truly independent.

The distribution system and its control - you know, Williams Pipeline pumped alcohol through its pipeline virtually successfully and had no problems - Arco pumped methanol through its own and dedicated pipeline all over the East Coast with no problems, and yet today in your conference we were told that in Alberta it was determined that the distribution system did not presently match with the use of alcohol fuels. Somebody has to be out there saying. "wait a minute, guys, that's not completely true". We can make the distribution system fit or not fit, as we choose to. I learned a lot about distribution when I found out that MTBE and the pipeline kept us from blending, made life real interesting when all of a sudden your markets dry up. Well, I think we need to go ahead and explain to people how, for Mohawk, labeling works, but for most other people labeling's confusing. If you label something different in the gas lane you have to then spend money explaining what that difference is. If tomorrow we put labels on all gas lanes that said 'this product is a carcinogen', I can assure you that it would not be very long before gasoline companies were out explaining that 'yes, it was a carcinogen, but it wasn't any different than it was the day

before'. Well, if you put an ethanol label on, you can do as Mohawk does, and as Energy Fuels does in New Mexico, you can try to tell that convincing story with it, but you're always having to spend money and effort telling that story because they do not know you're making a trade-off, behind the scenes, that basically it's just one more additive to gasoline. And then, I think you have to recognize that the gasoline change has been going on; increase in volatility, increase in aromatics, have already caused problems with automobiles and that if you label or if you talk about the subject very much, you will become, as we have in the United States, the target for the complaints of those automobiles. The complaints from those two-cycle engine manufacturers, the complaints from anybody who's concerned about the communist conspiracy still.

We finally had a problem - we got so frustrated with it, that we put in a warranty - we just decided "what the heck, we'll do what Arco did when they were worried about this - little old Energy Fuel said 'O.K., if your car is damaged by our E2000 Ethanol, we will fix it'". And we will send you to one of these - and it's now up to about eighty-five in New Mexico - there're only a million and a half people in New Mexico so - at one of the eighty-five independent Ford, GM, Chrysler dealerships that we've set up as warranty centres - and if that independent mechanic tells you that your car was damaged by our ethanol, we'll pay for it. Two years later, we've spent $85 on warranty repairs by the independent people. We've also spent probably $20,000 buying steak dinners for independent service people trying to get them to pay attention to issues about learning about gasoline. Those poor guys have had the cars change on them every six weeks - you know, everytime a new car comes in from Detroit or Europe it has something different on it because of environmental controls, and also trying to beat the 632 standards, and also this and also that, and at the same time the gasoline was changing - how in the world could they ever try to keep up. So we buy them dinner and try to explain gasoline, it's, I would suggest, even worse than listening to me.

Now, why's it so hard? Well, I think that we've gotten in a situation where most of the affected industries take a negative view of gasohol. Take a negative view of methanol - Mobil is now advertising in full page ads against methanol while Chevron and Arco are selling it on the West Coast. And they're talking that those affected industries are increasingly negative because they have nobody explaining that this is a way out of some of their problems. They only have their own internal people, talking among themselves, and saying "what are the real problems?" Now, as usual, whenever industry makes up its mind which way to go - and I think slowly but surely the oil and motor vehicle manufacturers are making up their minds to move against gasohol, Congress is moving the opposite way. Congress is extraordinarily positive about the alternative fuels. In the Presidential Debate, we had both Governor Dukakis and Vice-President Bush making positive statements about gasohol. I think that, at least in the United States, that after the election things will get better on a political basis, which is going to do nothing but make motor vehicle manufacturers and the API madder, not happier. They're going to fight harder, not less hard, because, especially with a new administration, they want to get their point of view across. And so, I would suggest that we're going to have a whole bunch more nasty stuff said about the industry at a time of extremely low oil prices, extremely high grain prices and lots of other confusion. But I

would like to remind you of something which happened that's important to Canada and important to the United States, and it happened in a very short time and very recently. Public policy can make an enormous difference and can make it very fast. I would like to remind you - not about the acid rain that's still under argument and discussion - but I'd like to remind you of the issues of solid fuels in 1975. In the United States they decided that 1.2 pounds of SO_2 per million BTU were the maximum limit from a new stationary source and from that moment on, the coal fields of Indiana and Illinois started to shrivel and Powder River Basin in Montana and Wyoming exploded. We completely switched fuels and adapted to regulations.

Terry Daynard, Chairman Session 4

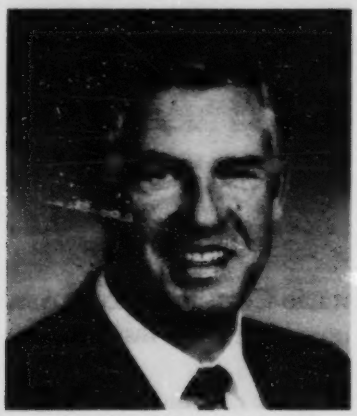
Executive Vice-President, Ontario Corn Producers Association, Guelph, Ontario and President, Canadian Renewable Fuels Association.

Terry graduated from the University of Guelph with a Ph.D. in agriculture in 1968 and did a post-doctorate at the University of Kentucky. Since 1969, he has been a faculty member of the Department of Crop Science at the University of Guelph and since 1972 has owned and operated a cash crop farm in Guelph township.

Dr.Daynard has worked tirelessly for the Canadian Renewable Fuels Association to provide farmers with an opportunity to diversify sales options.

W.J. (Bill) Hillier, Manager of Technology, Sunoco

Bill graduated from the University of Waterloo in 1964 with a BASc and from the University of Alberta with a M.Sc. in 1966. He has been with Sun for 25 years. Before becoming Manager of Technology, Mr.Hillier worked in Philadelphia and then in the Sarnia Refinery as manager of Technical Services.



Glen Perschbacher, Vice-President, Petroleum, United Cooperatives for Ontario (UCO).

Glen joined the cooperative system in 1959, and has since held various managerial positions. As part of his ongoing professional development, Glen has taken marketing courses from the University of Western Ontario, and management courses from Michigan State University and the University of Guelph. His responsibilities include the procurement, distribution and marketing of gasoline, diesel fuels, heating fuels, and propane, supplied throughout Ontario by the co-op system.

TECHNICAL/MARKETING OF TAILORED ALCOHOL BLENDS

by

MR. BILL HILLIER
SUNOCO
NORTH YORK, ONTARIO

Thanks very much Terry. It's very good for Sunoco to be here. I enjoyed the session yesterday. I have a background of being raised on a farm, so I can appreciate some of the things that you were all talking about yesterday. Can't say that I agreed with everything that happened yesterday, and I'll have a few comments as to what may be from an oil company perspective - some of the things that I see are maybe not entirely in tune with what I heard yesterday. I found the Conference very interesting and very well managed, and I'm enjoying it very much.

Just to give you an idea of where I fit into the organization, Sunoco is the downstream part of the Suncor organization. We have an oil sands group, and a resources group in Calgary, and then Sunoco is the downstream refining, marketing, crude supply organization. I fit into what's called logistics and resource management, and that includes the refinery, crude supply, product supply and technology. More specifically, my function is related to product quality and specifications associated with our products, insuring that they are competitive and up to date with the latest standards. In addition, we're looking at long range facilities planning for the Sarnia refinery; looking into the 1990's and seeing where we will fit into that in terms of facilities planning; and then another area that I'm involved in is new business development, and I should say that is related to the fuels area. Sunoco is not in the process of looking at a great diversification into other areas - we're concentrating in the fuel area.

I guess in terms of background, Sunoco has a number of, in addition to the retail brand, Sunoco brand, we have a number of unbranded stations, and one of the brands I'm going to talk about this morning is one that was set up in 1985 in a joint venture with Alberta Gas Chemical, and it's an unbranded group of stations that came originally from the Turbo, we purchased them from Turbo. In terms of the agreement, it's quite simple and I'm not going to go into it in detail, but basically Alberta Gas Chemicals supply the alcohols, Sunoco supply the tailored hydrocarbon blend and the technology associated with that, and Sunoco supply the managing of the stations, so that we're managing stations, and we've oxygenated at this point about fifty stations, and we've oxygenated only the regular unleaded blend.

So I'm going to go and talk a little bit about the marketing side, which is really not my responsibility, but I guess they send a technical guy to talk about marketing rather than a marketing guy to talk about technical issues. And then, I'll talk about some of the difficulties we actually have in blending and marketing this product, and then go on and talk about some of the technical issues that may raise questions at the end.

And as Terry said, Glen is going to follow my presentation with some information on their tests, and I think it will flow nicely into what Glen has to say.

I'm going to talk about the technical and marketing of a tailored alcohol blend at our V-Plus, and Comet Stations. V-Plus is the name of the product in those stations, and Comet was a series of stations that we purchased, I guess it was a little over a year and a half ago, and some of those stations have been oxygenated as well.

Terms of our objectives, we are trying to develop and explore a new product, which is our oxygenated gasoline. We've developed a lot of internal expertise over the years. As a matter of fact, when Barry was talking, back in the early '80's, '82 or '83, we did some tests with the Ministry of Transportation and Communications in Ontario of some very exotic blends at that time of methanol and IPA. Some of that work was actually used in order for us to learn what it would take to roll this out into the field, and that test was very successful, and we learned enough that we were very confident that we could roll it out into a marketing field trial. It turns out we've been into the trial for a long time, and it's no longer a trial, we look at it as a business opportunity at this point. But we wanted to develop sort of the market sensitivity and acceptance of the product, and I guess acquire a first-hand opinion through our experience of how this kind of product would be accepted, and into the marketplace.

Terms of our strategy developed an unbranded chain of retail outlets throughout Ontario, and then evaluate the marketability and profitability of the oxygenated gasoline. There's a few key things in that strategy, I think I'd like to emphasize. It was in the unbranded chain that we were interested in, and we wanted to see from a real marketplace point of view how well it did, and then, of course, develop the profitability of the venture.

The size of the network we started in 1985 with 42 retail outlets and we presently have 53. Not all of them are oxygenated - 49 are, as a matter of fact, and they go all the way from Kingston on the east side, Kitchener on the west, to all the way up to Sudbury and south to Hamilton. In terms of the sales, what kind of experience we've had. We've sold 132,000,000 litres of this oxygenated gasoline since 1985, and we're pretty much on the same course in terms of volume in 1988 here.

We learned quite a bit about how to convert the stations into an oxygenated site, to accept an oxygenated type fuel, and it's very important, the housekeeping and the cleanliness in order to make sure that it rolls out smoothly. So we have to clean the tanks and, in some cases, the fill pipes, the grating around the fill pipes were such that, in the wintertime especially, you could have the moisture getting into the fill pipe if people were careless. So we took the precautions of moving some of those fill pipes up, we added filters on the pump houses, then we advertised that it did, in fact, contain alcohol and stickers were installed on the pumps. The product quality was maintained through the special tank bottom samples that we took, and then, in fact, we looked at and made sure that there was no free water at the bottom of those tanks. There was a

special paste that we used that was very sensitive to water. Depending on the station, it cost $500 to $2,000 to do this kind of conversion, so, you know, it's fairly, fairly expensive. Operationally, we really have to be careful about the water and any water contamination, or otherwise, we would get ourselves into trouble and we went to great pains to make sure that we didn't run into any trouble. And I can assure you that we have not run into any trouble. It was in my group I thought we would have to add half a person just to do the techinical service and support of this product. It turns out that it's almost like a non-event. I think that's really a result of the research work and the development work that we did prior to introducing it into the field.

We did some - you know, we went out and asked the customers how aware they were of this product and some interesting things came back. In terms of people being aware that the gasoline contained alcohol, there was very low awareness. You asked a sample of customers did you know this gasoline contained alcohol? Very few people knew it. So, you ask the question, why do you come into our station, why did you buy the product? And in terms of hierarchy, again service is quite important - friendliness, the speed in which we service the customer, ease of access, some of the things that are standard to any good retail operation, but one most significant thing that drew people in was the price, and I think that this points out the fact that people take a look at that price that's advertised on the corner of each of our streets across the country. So that these things were probably more influencing to people coming in than actually our gasoline quality, although, from the other side of the coin, there weren't any complaints that came back from the customer saying we didn't like the quality of the gasoline. However, there were a number of customers who indicated because they were aware that the product contained alcohol and methanol - most customers wouldn't necessarily know the difference between whether it's methanol, ethanol, IPA, whatever. They definitely perceive a sort of positive characteristic associated with the alcohol, and they had some things to tell us related to - they felt it was clean burning, the car performance was better, it started easier, and a lot of good things like that. So, I guess the bottom line on this, we have not particularly exploited the marketing of this product by mass media advertising. We've done local advertising, and we haven't exploited anything with respect to what the product would do in the wintertime, what the product would do to the environment, any of these things, but overall, it's been the people that are aware tend to say 'hey, this is good gasoline'. As a matter of fact, as you'll see later in the logistics of this, we have a problem maintaining oxygenated gasoline in all stations at all times, because of our blending. And sometimes we have to dump regular unleaded into those tanks. And there are people that come back and say 'hey, that's different gasoline than what I filled up with last week', and we have to tell them that it doesn't contain alcohol because of the logistics of our network.

In terms of our blending, we blend up a special batch of hydrocarbon at the Sarnia refinery and it's shipped by the pipeline, the Sun Canadian pipeline, from Sarnia to Hamilton. And the components of methanol and the co-solvent are delivered by tank truck to the Hamilton terminal and are blended according to approved standards. We compute what our quality should be, coming out of the Sarnia refinery, such that when the alcohols

are blended, it will meet all our quality specifications. I'll talk a little more about that as we get into the technical part of it. So we just have, like, one storage tank in Hamilton allocated to this product and that obviously causes us some logistics problems with respect to a continuous supply. And then, once it's blended and checked out it's delivered through the network by our transports from Hamilton. You can appreciate one supply point that the delivery costs tend to be higher than normal, and that's part of what the Ontario road tax credit tends to offset some of these costs.

We've heard quite a bit about some of the benefits associated with oxygenated fuels, in terms of the atmosphere, in terms of octane enhancement and cleaner burning and reducing deposits in the car engines. As I say, we have not exploited any of these, or tested them explicitly with our gasoline such that we could advertise explicitly. In terms of octane enhancement, this turns out to be a very small increase in our overall pool octane, but there is a credit there that's associated with the alcohols.

As I mentioned earlier, this is not easy, it's a lot more difficult than our normal operation from a supplier, refinery, terminal, etc. point-of-view, but we have to arrange for the supply and it sort of, in a lot of cases, complicates our business. We're selling in Ontario and Quebec, the major part of our gasoline is not this. So you can appreciate the fact that when we have to make this blend, the pipeline - you've got to schedule a special pipeline for shipment, we must handle extra inventory in our Hamilton terminal and in the refinery, the tailored hydrocarbon blend actually ties up a regular unleaded tank for a period, and the procedures are just not normal. However, over the years, we've done this many times and the refinery is very good at making the product, the tailored hydrocarbon blend on spec such that it meets our other specs when blended with alcohols.

Just a few points about the blending of the tailored hydrocarbon blend. We obviously have to back out some like components in order to allow the alcohols in, and of course, we try to select the hydrocarbon components that are - what we'd like to do is back out and include in the tailored hydrocarbon blend a low octane, low volatility type component. We don't have all the facilities at the Sarnia refinery to do this in an optimum way, and you'll see later that we actually give away quality. The customer benefits, but we do give away quality. Suppose that this was expanded into the future, we would make the proper changes at the refinery such that we would not give away octane.

The terminal operation is kind of abnormal as well. We can appreciate, here we are at the Hamilton terminal and we receive a portion of the tailored hydrocarbon blend down the pipeline, and after we receive some of that, we add into the tank the methanol and the IPA, isopropyl alcohol. Then we complete the shipment, and then we have to circulate the tank. So the whole process is - you've got to have the trucks there with the alcohol, and you've got to sequence this properly or you'll run into problems with either mixing or delays. Then once it's all mixed up, we ship the samples to our Sarnia lab to check out, and all the samples, all the shipments and the tanks must be cleared to meet our normal regular

unleaded specifications before they'll be released.

As far as retail, I guess one problem we mentioned earlier was related to the terminal operation as we're circulating and testing out this tank. If a station requires gasoline during that period, we can't deliver, so that causes us a little bit of pain. And in order to improve that we'd have to add additional tanks or other terminals. Upgrading of those terminals would be required, but it would be a fairly significant capital investment.

In the conclusion of the sort of marketing side, we're satisfied with the oxygenated gas for V-Plus and Comet. That's part of our secondary brand strategy, and we'll expand gradually, providing economics warrant. I think the second conclusion is that we'd like to continue with the present mode of operation with V-Plus, and sort of develop and evaluate the marketability of the product a little bit more into the future. We have not really exploited that one to any degree at this point.

Now, I'm going to talk a little about the product technology side of it and a few details of how we progressed in our blends. We started in 1985 with a blend of 3% methanol and 3% iso-butanol, and gradually switched to increase the amount of methanol and iso-butanol from 3% to 3 1/2%. I would say that we've been fairly conservative about the whole approach here, in that we were not wanting to immediately get to 3.7 weight per cent oxygen, 5% methanol - we wanted to try to stay away from that and I think that's been a good strategy for us actually. In 1986, we actually got up to 4% methanol and iso-butanol, and we had to switch over to a different co-solvent, or I should say Alberta Gas Chemicals had to find a different co-solvent for us, and the methanol/iso-propanol approach was taken. We're currently at about the 4% of methanol and iso-propanol.

All our products meet all the specifications for Sunoco regular unleaded gasoline, and I think that's pretty important. We feel that it's we've developed the specifications over the years for RVP, distillation and octane in order to satisfy a certain car population, a certain user group, and we're not about to compromise that in any of our specifications. CGSB is working on a specification for oxygenated fuels right now. We've had no abnormal dealer or customer problems. It's been amazing, actually to me that we haven't had any incidents other than the standard ones that you would expect in any regional network.

As I said, we control the volatility by adjusting the butane and pentane portion of the gasoline, and I'll show you some qualities later on here of some typical summer and winter gasolines. We feel it's important to tailor make that product, and it's not a product that we would call a splash loaded type product. Each batch is tested prior to release, and actually the quality exceeds the CGSB minimum standards by significant portions. The other thing that we do is our multi-functional additive package is injected at Sarnia refinery in such a dosage that we feel that we've got excellent protection for the port fuel injection, clean up, for stability, and cleanliness within the engine. One of the things that people are concerned about is the corrosion protection, and we actually add an additional relative to our regular unleaded corrosion protection on the V-Plus, and in the final analysis it's really equivalent to our regular unleaded gasoline.

So, overall, we feel that quality control is important, and we've learned a lot over the years. From a technology point-of-view, we think we've learned all we need to learn. We don't need to be out in the market any longer to gain further experience. We've done different things, and we're going to talk in a couple of minutes about the extension of a test that's been going on with UCO.

This gives you a flavour for our actual volatility, octane and some of the other specifications on typical summer and winter gasolines. You can see in the summertime we have to back out butanes and pentanes in order to get the RVP down. We don't have exactly the right component to replace them with and therefore are giving away octane and our (R+M)/2 is 90.4, in that range, typically in the summertime. That happens to be quite a bit above our specifications, minimum specification of 88 and a half. In the wintertime, we're able to blend a little closer and our (R+M)/2 is 88.9, so we do a better job of coming closer to the specifications in the wintertime. The corrosion, copper strip corrosion test, is excellent and typically we have gone beyond the 4% in the 4.4% range for methanol and IPA.

O.K., I'm going to switch gears a little bit to lead into Glen's talk actually. We have a test that's been going on since October of '87, which involves participants of Sunoco, AGCL and UCO. Again Sunoco supplying the tailored hydrocarbon blend, AGCL supplying the alcohols, UCO supplying the marketing of the product in a couple of stations. Phase I of the test was to use a methanol/ethanol blend because of the forces of ethanol use in the farm community, and again I'll let Glen explain all that. Initial test went from October to June of '88, and we're supplying this tailored blend to two stations. Currently we have a test going on that, with the objective of possibly creating a common blend for UCO and V-Plus. The product is 4.3% methanol, 2.1% ethanol and 1.6% IPA. That test has been going on since July. It's still going on. It's October right now. The test has been going fine, as far as we know and Glen will talk about that. We are doing some vehicle driveability, summer driveability testing at our applied research and development organization. That testing has not - it's just started as a matter of fact, there were some delays in getting that going, but we're kind of interested in seeing if we can proceed. Significant driveability demerits associated with this type of gasoline versus our regular unleaded. From what I've heard so far out in the field, they haven't experienced any complaints or problems associated with the period July through September here.

So in terms of the present situation, the current economics, including the Ontario Road Tax Rebate, are unfavourable. This is not entirely an economic winner for AGCL or Sunoco. There's a number of things that have to be discussed in terms of making it more favourable and I think Terry's going to talk about that. But it's not currently on the positive side - I'd have to say it's not currently on a very strong negative side either. The future really depends on the cost of alcohols relative to gasoline and any expansion that we would have requires capital to upgrade our logistics capability. You can see the many constraints that we have in the logistics and the cost of that distribution, and if one was expanding significantly, you'd have to do something more permanent than what we're doing at our Hamilton terminal.

So, in conclusion, we are satisfied with the oxygas for V-Plus, as part of our secondary brand. And we will expand gradually providing the economics warrant it. And we're going to look at the marketing side of it to see whether there are some things that we could do to enhance our position from that point-of-view. So, that's about where we are and I guess I have a couple of other comments before I turn it over to Glen.

There's been a lot of talk about ethanol being something that will come about because lead - in terms of increased activity - because of lead phase down. I can assure you that Sunoco, and many other of the major oil companies, have already got their plans in place as to what they're going to do with respect to lead phase down. Most of them, including ourselves, have looked at it very carefully, and it's not the very next thing we would do. We have no plans of oxygenating our brand at this point in time. One of the other things that I heard yesterday as I was listening to the deliberations, regarding the oil companies, you can appreciate that we've made a significant investment in our down stream operation over the years. What has happened, we've had to shut down refineries, we've had utilizations that are not at capacity, were not at capacity, we've had low margins, we've had low return on capital employed. So anybody that comes along and says I'm going to back crude out of your refinery, reduce your incremental barrel, and the economics associated with that, you can appreciate that they're not going to look at that too favourably. Given, and then given the economics of the situation, you kind of have to sort of bring that all into being. So, I think the oil companies have been fair, in looking at this opportunity. I think Sunoco has been pioneer out there in the field doing things, and doing tests with UCO, and we're proud of that. We don't know exactly where it's going to go, but we know what to do if it ever takes off.

So, thanks for the opportunity to talk to you and if there are any questions I'll be glad to answer them.

OXYGENATED GASOLINE

OBJECTIVE

- DEVELOP AND EXPLORE A NEW PRODUCT (OXYGENATED GASOLINE)
- DEVELOP INTERNAL EXPERTISE
- DEVELOP MARKET SENSITIVITY AND ACCEPTANCE DEGREE
- ACQUIRE A FIRST HAND OPINION THROUGH OUR EXPERIENCE
- BUSINESS OPPORTUNITY

STRATEGY

DEVELOP AN UNBRANDED CHAIN OF RETAIL OUTLETS THROUGHOUT ONTARIO AND EVALUATE THE MARKETABILITY AND PROFITABILITY OF THE OXYGENATED GASOLINE.

SIZE OF NETWORK

- STARTED IN 1985 WITH 42 RETAIL GASOLINE SITES
- PRESENT NETWORK HAS 53 OF WHICH 49 SITES ARE OXYGENATED
- GEOGRAPHY -

  EAST = KINGSTON

  WEST = KITCHENER

  NORTH = SUDBURY

  SOUTH = HAMILTON

- SALES OF OXYGAS SINCE THE BEGINNING OF PROGRAM - 132,000,000 LITRES

  (Y.T.D. MAY 31 = 20,000,000 LITRES)

RETAIL SITE OXYGENATED CONVERSION

- TANKS NEED TO BE CLEANED
- GRADING AND FILL PIPES ARE INSPECTED AND MODIFIED WHEN REQUIRED TO PREVENT ANY WATER FILTRATION
- ADDITIONAL FILTER INSTALLED ON PUMP HOSE
- ALCOHOL CONTENT STICKERS INSTALLED ON PUMPS
- CONSTANT PRODUCT QUALITY MAINTAINED THROUGH TANK BOTTOM SAMPLES AND SPECIAL WATER PASTE
- COST OF ABOVE $500 TO $2,000
- OPERATIONALLY - SPECIFIC CARE HAS TO BE GIVEN TO THE PRODUCT TO AVOID WATER CONTAMINATION OR OFF SPEC PRODUCT.

CUSTOMER AWARENESS

1. THE AWARENESS LEVEL FOR V-PLUS GASOLINE CONTAINING ALCOHOL OR METHANOL AMONG REGULAR/OCCASIONAL USERS, IS LOW.
2. IN THE STRATEGIC HIERARCHY OF REASONS FOR SELECTING V-PLUS, FRIENDLINESS, SPEED, EASE OF ACCESS AND PRICE ARE SIGNIFICANTLY MORE IMPORTANT INFLUENCERS THAN GASOLINE QUALITY.
3. THOSE CONSUMERS WHO ARE AWARE OF METHANOL, DEFINITELY PERCEIVE POSITIVE CHARACTERISTICS TO BE ASSOCIATED WITH THE METHANOL INGREDIENT (CLEAN, CAR PERFORMANCE, EASIER TO START).

BLENDING

- UNLEADED SPECIAL SPEC GASOLINE DELIVERED TO HAMILTON VIA PIPELINE FROM SARNIA.
- COMPONENTS METHANOL/COSOLVENT DELIVERED VIA TRAIN OR TRANSPORTS.
- BLENDED ACCORDING TO APPROVED STANDARDS.
- ONE STORAGE TANK (6700 M3) ALLOCATED TO THIS PRODUCT.
- PRODUCT IS DELIVERED THROUGH THE NETWORK VIA ROAD TRANSPORT. FROM HAMILTON (RESULTS IN HIGHER DELIVERY COSTS).

BENEFITS

- REDUCES OZONE FORMING COMPOUNDS AND CARBON MONOXIDE EMISSIONS INTO THE ATMOSPHERE
- OCTANE ENHANCEMENT
- CLEANER BURNING REDUCING CARBON DEPOSITS IN CAR ENGINES

V PLUS OPERATIONAL IMPACT

A. SUPPLY

- ARRANGING FOR THE SUPPLY OF V PLUS COMPLICATES THE NORMAL BUSINESS
- PIPELINE SCHEDULING CAN BE DIFFICULT
- ADDITIONAL INVENTORY MUST BE HELD

B. REFINERY

REFINERY BLENDING OF TAILORED HYDROCARBON BLEND (THB)

- TIES UP AN UNLEADED REGULAR TANK
- COMPLICATES BLENDING PROCEDURES
- NEED TO SCHEDULE SPECIAL BATCH

C. TERMINAL OPERATION IS ABNORMAL

- SEQUENCE
  1. RECEIVE PORTION OF THB
  2. ADD METHANOL/IPA TO TANK
  3. COMPLETE SHIPMENT OF THB
  4. CIRCULATE TANK
  5. SHIP SAMPLES TO SARNIA LAB

D. RETAIL

- DURING THE TERMINAL OPERATION, OXYGAS IS NOT DELIVERED TO V PLUS SITES BECAUSE OF LACK OF STORAGE CAPACITY.
- TO IMPROVE PRESENT SITUATION ADDITIONAL TANKS OR OTHER TERMINAL UPGRADING ARE REQUIRED; BUT INVOLVE HIGH CAPITAL INVESTMENT.

SUNOCO'S CONCLUSIONS

1. WE ARE SATISFIED WITH OXYGAS FOR V PLUS AS PART OF OUR "SECONDARY BRAND STRATEGY" AND WILL EXPAND GRADUALLY PROVIDING ECONOMICS WARRANT.
2. TO CONTINUE WITH PRESENT MODE OF OPERATION WITH V PLUS, TO DEVELOP AND EVALUATE THE MARKETABILITY OF THE PRODUCT.

OXYGENATED GASOLINE

PRODUCT TECHNOLOGY

VPLUS EXPERIENCE

YEAR	% METHANOL	ISO-BUTANOL	ISO-PROPANOL	OXYGEN
1985	3.0	3.0	-	2.3
1986	3.5	3.5	-	2.7
1986	4.0	4.0	-	3.1
CURRENT	4.0	-	4.0	3.3

- o VPLUS MEETS ALL SPECIFICATIONS FOR A SUNOCO REGULAR UNLEADED
  - RVP
  - DISTILLATION
  - OCTANE
- o NO ABNORMAL DEALER/CUSTOMER PROBLEMS

V-PLUS GASOLINE QUALITY CONTROL

- VOLATILITY (RVP, DISTILLATION) IS IDENTICAL TO SUNOCO UNLEADED GASOLINE
- PRODUCT IS TAILOR-MADE AS OPPOSED TO "SPLASH LOADED"
- EACH BATCH IS TESTED PRIOR TO RELEASE FOR V-PLUS AND THE QUALITY EXCEEDS MINIMUM CGSB STANDARDS
- MULTI-FUNCTIONAL ADDITIVES ARE INJECTED AT SARNIA REFINERY
- CORROSION PROTECTION OF V-PLUS IS EQUIVALENT TO SUNOCO'S UNLEADED GASOLINE

V-PLUS GASOLINE QUALITY

	SUMMER	WINTER
VOLATILITY		
RVP kPa	73	97
DISTILLATION: °C		
10% EVAP	43	37
50% EVAP	87	77
90% EVAP	173	170
EP	215	212
OCTANES		
RON	95.9	93.8
MON	84.9	84.0
(R+M)/2	90.4	88.9
OTHER		
COPPER STRIP CORROSION	1	1
METHANOL VOL %	4.4	4.4
ISOPROPANOL VOL %	4.4	4.2

ETHANOL PLUS TEST

PARTICIPANTS: SUNOCO
AGCL
U.C.O.

A. **PHASE I**

- PRODUCT: 2% METHANOL
  2% ETHANOL
- INITIAL TEST: OCT/87 - JUNE/88
- TAILORED BLEND SUPPLIED TO 2 STATIONS

RESULTS: VOLUMES HAVE EXCEEDED ORIGINAL EXPECTATIONS

B. **PHASE II**

- OBJECTIVE: CREATE COMMON BLEND FOR U.C.O. AND V-PLUS
- PRODUCT: 4.3% METHANOL
  2.1% ETHANOL
  1.6% IPA
- TEST PERIOD: 3 MONTHS (JULY - SEPTEMBER)
- FIELD TEST WILL BE SUPPORTED BY VEHICLE DRIVEABILITY WORK

C. **PRESENT SITUATION**

- CURRENT ECONOMICS (INCLUDING ONTARIO ROAD TAX REBATE) ARE UNFAVOURABLE

D. **FUTURE**

- DEPENDS ON COST OF ALCOHOLS RELATIVE TO GASOLINE
- EXPANSION REQUIRES CAPITAL TO UP-GRADE LOGISTIC CAPABILITY

AN ENVIRONMENTALLY SAFE OCTANE SOURCE FOR THE FUTURE FROM CO-OP ETHANOL PLUS - OXYGENATED GASOLINE

by

MR. GLEN PERSCHBACHER
UNITED COOPERATIVES OF ONTARIO
MISSISSAUGA, ONTARIO

Thank you very much for the opportunity of joining with you at the conference here these two days. What I'm about to say is not of a technical orientation, it's more on what we believe within United Cooperatives, or the Coop sector, and what we've done to date, and I'll try and bring you up to date with the results. And I don't know whether that's gone out of focus but it looks like it from here. Thanks, Terry.

As Terry said, United Cooperatives is a cooperative organization in the Province of Ontario, and I should maybe give you a little background on why we're thinking the way we are. We're in the farm supply marketing business, and we think we're a fairly major marketing organization to the farm public in Ontario, because we've got 48,000 farmer members, direct members within UCO, and we've got another 38,000 farmer members through the member cooperatives. So the Ontario cooperatives interest in ethanol, and basically we say that UCO and the member cooperatives are primarily all farmers. The use of ethanol as an octane replacement for lead in gasoline could significantly benefit our farmer members. So there's no question, a natural synergy exists between farm supply cooperatives in Ontario and fuel ethanol production. But most of our farmers are members - coops in Ontario are also in the grain marketing business, so we're interested in the grain side of the farm production and markets. Additionally we do market gasoline through our gas bars to bulk commercial customers and to farmers, including the other distillate products. And we are in the feed business, so the feed business is quite a major part of the cooperative's distribution in Ontario. We heard a fair amount yesterday about the DDG's and the by-products, we are a consumer of DDG's in our feed formulations because we do manufacture complete feeds and pre-mixes, so this is also of an interest. And basically, we're saying that ethanol manufacturing could result in new markets for grains produced in Ontario.

I guess it goes without saying, but I think it's worthy of saying, that the cooperatives do not have the expertise to influence the technical acceptance or production on the technical and economic side. We even took this to our Board of Directors which supported the direction that UCO play an active role in promoting a fair assessment of ethanol's potential as an octane replacement in lead phase-down, or as an octane source in gasoline.

Federal government, petroleum industry, automotive manufacturers, everything that we were able to find, we felt supported the fact that an E3M5 was an excellent type of product, so we focused our attention towards that. We also believe from what we could ascertain that an E10 would make an excellent premium fuel. We, as a distributor of petroleum in Ontario,

have been and are using and working very closely with Sunoco as one of our major suppliers of product and we were also aware of the work that Sunoco and Alberta Gas were doing in connection with their V-Plus organization and their V-Plus marketing. So, I guess, we said that if we could put this together and take a look at the DDG's and some of the other benefits we were very interested.

We also felt very strongly that ethanol provides an environmentally safe gasoline, and I've just borrowed a couple of slides from some of the information that we received from ADM, which, in some of their work they illustrate very nicely the carbon monoxide benefit being approximately 30% less, the hydrocarbon being slightly less and we knew that the American experience was very positive towards ethanol enhanced gasoline. Therefore, I guess we said we know it works, but we felt that no one was bringing it to the market, and as Bill said, I think it goes without saying but we understood it very well, that the petroleum industry were not out seeking ways to decrease production because they had just come through five to eight years of declining to flat markets, and we knew that because we were in it. Government incentives were not moving towards making it of tremendous interest to any of the groups, so we felt we should go out and ask the market.

The Ontario Cooperative's role we felt was to promote a fair assessment of ethanol's potential as an octane replacement. We wanted to determine consumer acceptance. And thirdly, we wanted to develop procedures necessary for safe handling. So in order to proceed, of course, we needed a tailored hydrocarbon blend of gasoline in order to produce a regular no lead gasoline with ethanol and methanol. As I stated, we were very much aware of the Sunoco/Alberta Gases experiment, which at this point had been going for two years. In addition, we went to them and suggested that we would like to be able to produce E3M5. We were able to work together and we certainly appreciate the help of Alberta Gas and Sunoco on the development of what we called our new product, Ethanol Plus. We developed an E2M2 as Bill showed you, which met all the technical specifications under the CGSB specifications for regular unleaded gasoline. The distillation curve was excellent, octane averaged about 1% higher than the typical refined no lead.

So we had our new product called Ethanol Plus and we proceeded with the introduction as Bill stated, we were selecting locations where to run our test, and we selected two locations, being the Guelph Gas Bar and the Listowel Gas Bar. Our Coop Gas Bar at Guelph is located on 24 Highway about a mile south of Guelph, and for those of you not familiar with Ontario, Guelph is an urban city with a population of about 76,000 people and it's basically a small industry and university city. Listowel Gas Bar is located at our site at Listowel on 83 Highway right on the north edge of the town. And Listowel is a rural/urban town with a population of 5,000, surrounded by good to excellent agricultural production land, and the farming production in the area is quite high in the livestock area, and I'd say mainly dairy, hogs and poultry with some cash crops. So the agriculture in the Listowel area is not strictly grain production. You could ask why did we choose these two locations - well, one of the major reasons was because of logistics, because we had to develop some storage for the product, etc., and secondly, is we were wanting to get a bit of a feel from

both the urban market to get some ideas whether the benefits were more from an environmental point-of-view, as well as, of course, go to an agricultural market to see what kind of response we'd get from the agricultural market. We introduced the product at the two locations on October the 21st at Guelph and October 28th at Listowel. And I have a few slides here from the introduction.

We decided to go with a fairly full-fledged press release and introduction. We decided to try and develop a fair amount of hype for the introduction because it was our objective to try and introduce the product to as many customers as we could and then monitor the response. So here we had an official ribbon cutting as an introduction where we had as you'll note Terry Daynard, our President, John Black, and our Chief Executive Officer, George May, cutting the ribbon. And I guess, you can see that we had a fair crowd of people around for the introduction of the product - and this is at the Guelph station - this is refueling the first vehicle. You'll see a TV camera - we had coverage from four TV networks were all there. Many of the major newspapers gave us coverage and pretty well all the farm press. So we succeeded in coming up with what I felt a very successful introduction and launch.

And again, just another shot, and you'll see our mascot the Co-Bear there. We have him at a lot of our promotions, trying to develop some enthusiam for the hype at the activities.

What did we find? Well, first of all we found that under consumer acceptance that were no preconceived negatives. At the introductions, we ran a customer survey where we had a questionnaire, and we had people talk to every customer, and there were no preconceived negatives whatsoever towards ethanol alcohols in the gasoline. We also found that on request we had 100% of the people try the product. There was no hesitation to pull up to the ethanol plus pump and try the product. Terry was at the Guelph opening and, I guess, we had cars lined right out to the highway waiting to get to that pump to try the product. We estimated that, from what we could ascertain, about 60% of the customers came back and bought the product on the second, third, fourth fill-up. When they were coming back and refueling in the vicinity of our gas bar, they were buying Ethanol Plus.

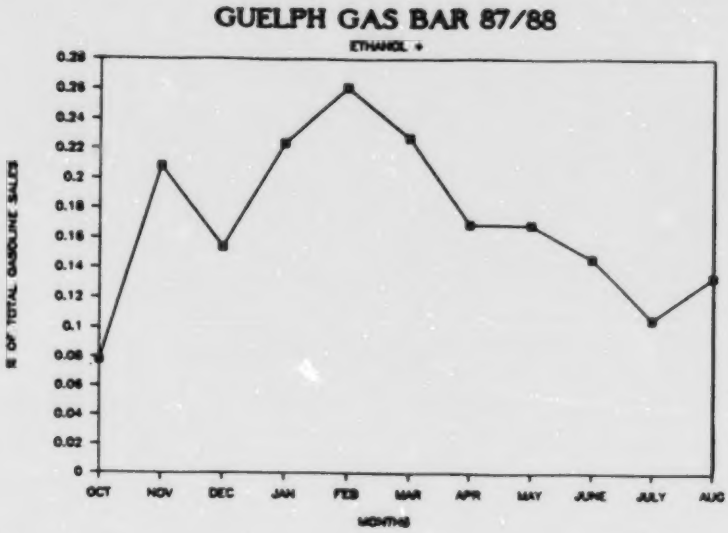
So, what were our test results? And here we have a graph from October to August of our actual sales of Ethanol Plus at the Guelph Gas Bar.

	Research	Antiknock Motor	(Road) $\frac{R+M}{2}$
CGSB Regular Unleaded Gasoline Minimum	N/A	81.5-82.0	86.5-87.0
Typical Refiner Regular Unleaded Gasoline	92.0	84.0	88.5
ETHANOL PLUS	94.6	84.1	89.4

(CGSB - Canadian General Standards Board)

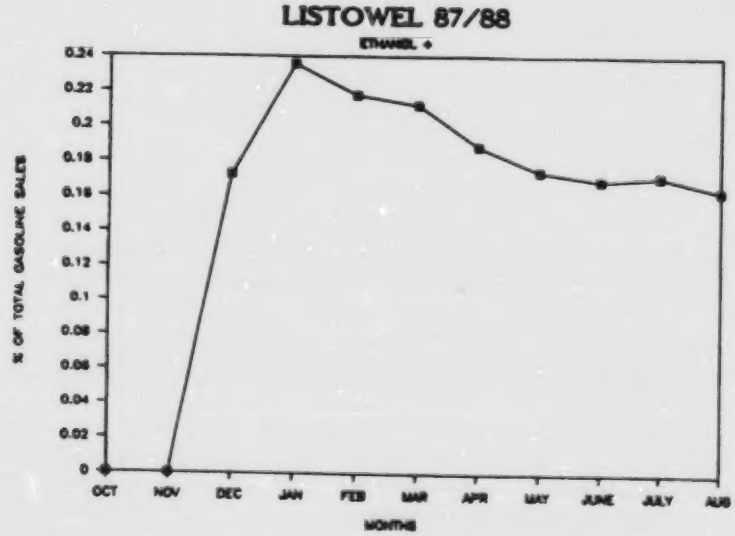
Ethanol Plus Test Market Results:

Guelph



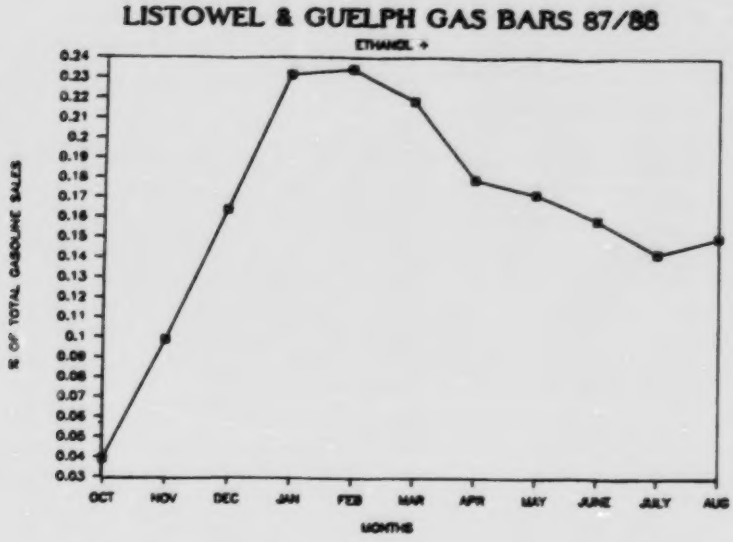
Note the average of about 15% of total fuel Ethanol Plus from one nozzle out of the six.

Listowel

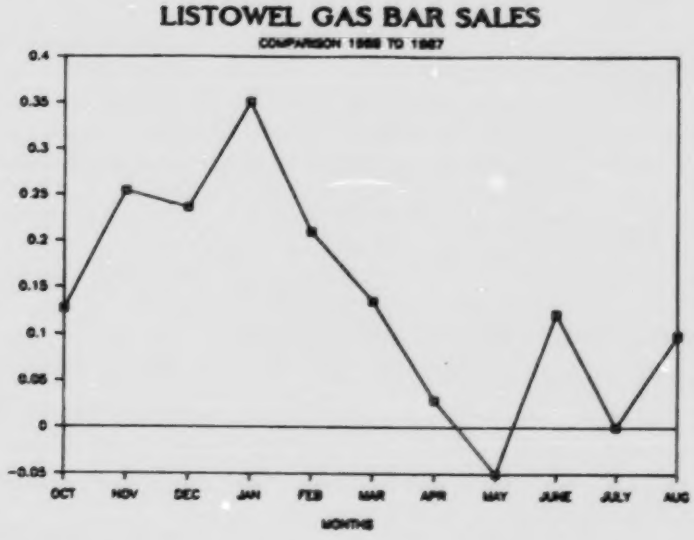


Average about 20% of of total fuel is Ethanol Plus from two of the eight nozzles.

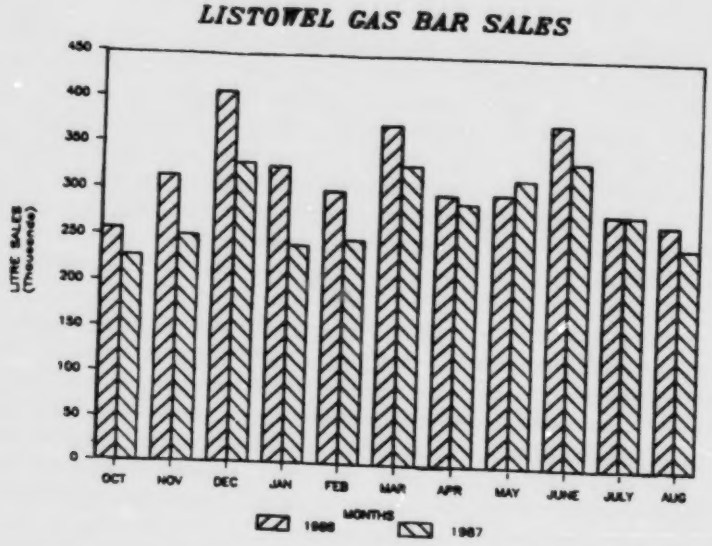
Combined



Effect on Sales



Total gasoline sales at Listowel gas bar. Note the May and July effect due to major promotion in previous year and road construction.



Ethanol Plus Test Market

2. Effect on Sales - Summary and Conclusions

1. No predisposition against ethanol alcohol gasolines.
2. Almost 100% willingness to try Ethanol Plus.
3. 60% to 70% customer retention.
4. Excellent quality product with good drive-ability.
5. Few customer complaints.

Ethanol Plus - Future Directions

1. Develop procedures to facilitate use of Ethanol Plus in on-farm storage tanks which is currently under testing.

2. Increase the potential distribution by attracting additional marketers to justify continuous supply ex refinery.

This has led to the changing of our Ethanol Plus blend being tested to include isopropyl alcohol, which occurred in mid August. Ethanol Plus now contains 4.3% methanol, 2.1% ethanol, and 1.6% isopropyl alcohol. Early results show no change in purchasing patterns, and continuance of excellent operational results. We are in the process of some promotional activity to remind our customers and potential customers of the new product.

PERSPECTIVES ON ALCOHOL FUELS

by

MR. TERRY DAYNARD
ONTARIO CORN PRODUCERS' ASSOCIATION
GUELPH, ONTARIO

For the last year and a half, I've been President of the Canadian Renewable Fuels Association as well as farming and my position with the Ontario Corn Producers' Association. And I guess I have the same problem a number of other speakers have had after about the first or second one. A number of the things that you thought you'd like to say have been covered well by the previous speakers, who probably covered them better than I'm capable of doing myself. I do want to touch on some of the things, and at the risk of being repetitive, that we see, as an Association are obvious benefits from fuel ethanol. One of the problems was it being a collection of benefits rather than individual benefits that make this sound sensible. It continues to sound sensible, even if we are in a situation right now - because of a one year drought, grain prices are particularly high, and because of other problems, oil prices seem to be in a particular low period of time. We think that we're looking for the long-term, the long-term being the 1990's and thereafter. And we remain just as much committed to this concept when oil is $13.00 a barrel as, I guess that it closed at last night, as when oil is $25.00 a barrel or prices beyond, or even when corn's selling for $150.00 a tonne as it is in Ontario right now as opposed to about $80.00 a tonne before the drought affected us this past summer. Those benefits, I think, are pretty straight forward.

The octane value of alcohol, and that's been covered in detail by a good number of speakers, we see this as a viable alternative to the octane that has to go in there from some source as lead is removed, perhaps at some time when Canada catches up to the United States and takes a look at the MMT content in gasoline as well. MMT is used in Canadian lead-free gasoline and banned for this purpose in the United States, for environmental reasons. We base much of our analysis on this - the materials have been supplied by Energy, Mines and Resources in Ottawa, and in turn based heavily on a study done by Howard Carp Consulting in Calgary which showed in the absence of lead and MMT, that the alcohols or alcohol blends represented as cost effective means of putting that needed octane in there for a typical refinery situation. That doesn't mean for an individual refinery necessarily. As cost effective as the other options were available for the refining other ingredients that could be added - MTBE and so on. And we emphasize in particular in the case of E/M blends, ethanol/methanol showed to be particularly attractive. The E10 blend that I'll be talking about a little bit more, wasn't as attractive from that standpoint. So, we think that it is credible from that standpoint.

A lot of attention being paid over the last year to the question of enhancement of light crude supplies, and energy security in this country akin to what's going on south in the United States, and obviously, there are differences of opinion as to how critical this is to the country.

Michelle Heath pointed out yesterday the numbers that best case scenario says by the mid-1990's we'll be importing about half a million barrels of light crude oil a day into Canada, and at a price around $15.00 a barrel - that works out to about $5 billion a year. So it is a drain on foreign exchange and it's an opportunity. I suppose whether it's plus or minus depends on whether you happen to be involved in importing that crude and the opportunity that creates to you as well. But certainly the Canadian Government seems to have identified that as a problem, and means to do something about that. Very recently, they've made a substantial commitment to three mega-project proposals, with a primary reason for doing that being this light crude oil situation. And the numbers that come out from the Canadian Government, from EMR, say that ethanol/methanol blends or, if you use their numbers and put them together with other data that's available, say that ethanol/methanol opportunity makes just as much sense, if not more so, than the three projects that have been committed to date. And certainly in security of supply, we think we can stand up and argue with anybody that we've got a good security of supply with biological materials, and even if we were to see the extreme of 10% of all gasoline in Canada have 10% ethanol in it, and all that came from grain, we would still be a major grain exporting country. It amounts to about 8,000,000 tonnes of grain potentially, and typically we export somewhere in the neighbourhood of 20-30,000,000 tonnes of grain out of this country.

We think it makes sense from the environmental standpoint. We're somewhat frustrated at the lack of interest shown in this country in carbon monoxide, and the major attention is being given to it in the United States. Part of it is that our levels are 50% higher, what we tolerate here, than they are in the United States, but I have difficulty understanding if all up the east side of the Rocky Mountains in the United States, you have carbon monoxide problems, why there aren't carbon monoxide problems in Calgary. I have difficulty understanding why Cleveland and Detroit are under major pressure as non-compliance areas in United States of carbon monoxide to do something about it and do something about it under the legislative power of EPA, and somehow it's not a problem in Windsor or Toronto. The carbon monoxide issue has been dealt with before. Obviously we can argue that as we are using current biological projects, it's a net zero contributor to the carbon dioxide balance.

Finally, the ozone situation, and to some degree in this country, we feel we've got a bit of a bum rap. Various sources suggesting that, if we go to oxygenates, we're going to move in the wrong direction on ozone. That may be the case, if indeed you accept a higher rate vapour pressure with an oxygenated blend, but it has not been the position of the Canadian Renewable Fuels Association that we want that to happen. Through some of our members that are more technically competent than I am, who pointed out that there's some anomalies apparently in the distillation curve with an oxygenated blended gasoline versus the normal product, and the uniqueness of the temperature at which Reid vapour pressure is measured. Nevertheless in our view, that would be a step backwards to be promoting a product that is a contributor to ozone pollution, and it has not been the position of either the Canadian Renewable Fuels Association or the Oxygenated Fuels Association that there should be a higher tolerance for Reid vapour pressure for oxygenates in gasoline than for the regular product.

Fuel alcohols make sense from a regional development standpoint. We think that they make sense from an agricultural standpoint, although we recognized very early that if we were trying to sell this thing totally from an agricultural perspective, the arguments didn't stand up to full credibility, and we would be hit with the suggestion as we have been at this conference, that if your goal is simply to subsidize the farmers, that there's a better way of doing that. We've never heard anybody question the Hibernia situation as to whether that was the most economic means of getting money to Mobil, or whether you'd be better just to give them $3 billion off the top, but somehow that question comes back when we talk about the agricultural implications, and we think it's a combination of all of these things. Value to grain use in east and western Canada - if this thing takes off, we don't grow enough grain in eastern Canada to supply the needs in Ontario and Quebec - we'd be looking at western grains as being a source of ethanol down there as well. And we have nothing to fear if it moves to cellulosics being the feed stock - we grow lots of that on farms, and we could grow an awful lot more if the market opportunity was there as well.

The by-product, Don O'Connor handled that in detail. I can just emphasize a few of the things in Ontario. Wet distillers and brewers grains that come out of breweries and distilleries in Ontario are highly valued by the dairy industry. The biggest problem that they have is continuity of supply and a dairy farmer just insists on having a consistent feed ingredient going to his livestock. Unfortunately, brewers tend to work much more dilligently in the summer than in the winter, because of seasonality of beer demand. The distillers tend to operate a few months of the year at the moment because of the declining consumption of their product, and the dairy farmers have problems relying on that. If you get an alcohol plant set up that's committed to run 365 days, they want somebody to use that product 365 days. The dairy farmer has to feed those cows 365 days a year, and it seems to be a natural, and certainly experience in Ontario would amplify everything that Don O'Connor talked about.

A little bit about the negatives, and there have been a number of these. The question about grain prices - grain prices go up and down. If you had to depend on grain price, if you're in this business depending on grain prices, obviously they're not a constant. Well, I guess from our point we would agree that that's the case, but if you look at the ups and downs in the grain prices over the last two decades, and you look at the ups and downs in the oil prices, grain prices tend to be virtually static. You also look at historic trends. Regardless of what's happened in the last few months, if you take the pattern on real grain prices within Canada, and it doesn't matter whether you use barley or wheat or corn, it worked for them all, adjust them for inflation, the price of grain right now is about a third of what it was, even with the drought-induced increase, back in the 1950's. The price of oil, I can't give you the exact figure, but in real dollars it's significantly more than it was back in the 1950's, even with the plunge that's going on right at the moment. If you extrapolate that into the future, even with the variability there is around it, I don't think that we have to apologize at all as to what might lie ahead in terms of using grain as feed stocks, and if it becomes cellulosic materials, it will be because they're even a cheaper means of making it. And there are mechanisms available to the trade to hedge on grain price

fluctuations, just the same as there is in the oil business.

We have the question about refinery jobs and that's a real problem. We admit that, and we've had a fair amount of sympathy to it, until the oil industry has said that if they have to go to a source of octane to replace lead, an obvious one they want to go to is MTBE. Well, as I understand MTBE is going to be blended in at about 11% of the mix. Alcohols, we're talking about somewhere in the neighbourhood of 8-10%, and certainly in that kind of a comparison, we don't see that the alcohols are a disadvantage relative to the MTBE which is being actively promoted elsewhere in the industry. From a national standpoint, it is reasonable to ask what's the balance between refinery jobs as opposed to job creation elsewhere in the economy, and as opposed to the vulnerability you have on light crude imports to supply those refineries, if indeed things go as projected.

Questions about transport of the material, water contamination, compatability - I think those have - lots of questions raised in that area. Our impression is that sometimes those are raised as being bigger problems than they really are. I think that probably I really can't add to the kind of comments that came from Bill a few minutes ago, from Sun's experience when they looked into this. Some of them need some attention; some of them turned out to not be the difficulties that were envisioned. If you look in the United States, as you'll see when ethanol was attempted to be introduced there, there were all kinds of problems thrown up as to what might go on, and now virtually everybody in the industry down there seems to accept that it's a credible product. Certainly the auto industry seem to, and we have a sense that the same situation may lie ahead with methanol as well.

Vehicle warranties, there are problems with vehicle warranties if methanol is in the mixture. Some of them we understand, some of them we don't. I was looking through the material that was circulated in front of you, and I noticed to my amazement that Mercedes won't warrant a vehicle that's got an ethanol/methanol blend even though, as I understand, most of the gasoline in Germany has methanol in it, and Austria, that it all has methanol in it and some kind of a co-solvent - it's clearly not ethanol that they're using. But again, as I understand, the differences between the co-solvents, and I guess as the two previous speakers pointed out, seem to make marginal differences on the quality of the fuel.

The final question is economics. And those that have attacked us have focused on E10, and we accept and we've acknowledged that E10 can't make it, certainly in the present environment, unless it gets the kind of support that it's had in Manitoba, or it has in the United States. As an organization, we haven't come out opposed to E10, but we've put our focus on other things. We've put our focus on the ethanol/methanol blend and we submit that the economics are vastly different, and I don't know anybody who has looked, in a public sense, at the kinds of things that Mohawk are doing with the E5 blend, a premium market for a premium product.

As far as government role, I think that we have had a very positive response from the provinces, from every province from Ontario west. We have no complaints about what the provinces have done. In fact, we think that the provinces in general have been far-sighted on this thing. Manitoba clearly takes the lead, but other provinces have come along as

well. We're pleased with what Ontario has done, as an Ontario farmer, on this sort of thing. At the same time, the oil industry and the fuel business in Canada is national and we just simply can't see how you can make it work with a different incentive programme in each province. There's got to be a federal leadership coming in this area, and to this stage, we've had little or none. That's a bit disappointing to us. I think that we had reason to expect a bit more. In the hand-out that I've prepared, I've put a statement in there that - I don't intend this to perhaps be as political as it might sound, being as how the election was called a few days ago - but the present Prime Minister, we felt made a very clear commitment to alcohol-blended fuels about four years ago now, and we don't believe that that commitment has been honoured. There have been lots of studies done on this, there are more studies, but when we come in and ask for something, like an excise tax break, regardless of what Tony Taylor said in the first speech yesterday morning, we don't think that's unreasonable. It's not unreasonable relative to what they have done with propane and compressed natural gas. In fact, on those there is no sales tax either, federally on compressed natural gas, and very little on propane. We have simply been asking for the excise tax. The excise tax was a sin tax, as somebody pointed out, to discourage consumption. The excise tax was indeed part of the national energy programme that the present government seems to be quite pleased to condemn at every turn, but somehow this little part of it they never, ever talk too much about.

When we have the word from the folks in Ontario saying that that looks like it's what's going to be needed to push that over, if nothing else to overcome these extra costs that are involved because of the relatively low quantities and the special treatment that it has to have through the Sun/Alberta Gas Chemical/UCO system, we think it's a reasonable request. And it's not big dollars. We've calculated out if the excise tax, if 5% of all the gasoline sold in Canada was 8-10% alcohol, depending on the particular blend, we'd be talking about a cost to the federal government of $8,000,000 a year. They can't even count that low. In fact, maybe our mistake in strategy is we should add a couple more zeroes on it so it could look credible.

I'm reminded of the chap in Cambridge, and this is a true story, that was making top quality boats and couldn't sell these things. In desperation, he went to the University of Waterloo which has an excellent programme of trying to aid the small businessman, as to what he should do about this, and he just basically said the dollar figure isn't big enough. Double the cost of these boats, which he did and he's prospered ever since, so maybe that's the approach we should be taking to the government on this thing as well. I would suggest to Ken Beswick though, even from Alberta, that I hope that the Alberta government applied the same criteria to making its decision, whether it's going to invest in Lloydminster as it has in the alcohol business, and I suggest that if the same criteria had been applied, we might have kind of a different story coming from there.

In summary, we see that we've got an uphill battle. The speaker last night pointed out very clearly some of the hurdles to overcome, and I look at how well organized the Renewable Fuels Association or the renewable fuels movement is in the United States, and the lack of resources we're trying to operate on, at least they have the advantage down there that

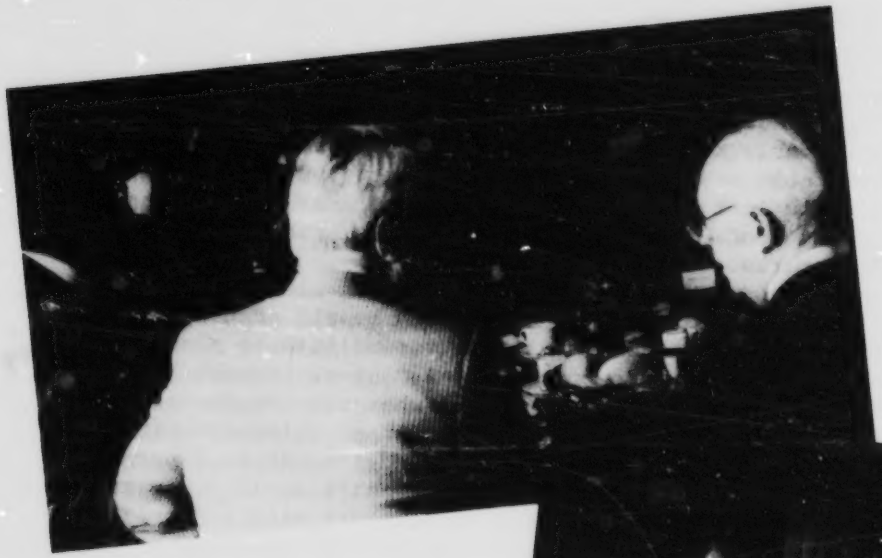
they're fighting on the basis of revenue coming in from an established industry - we're trying to get one going here. We think though that what we're promoting is credible. We think it's in the national interest. It may not be able to be sold on any particular criterion, but if you add them all together, and if you look at the other things that our governments are doing in the energy interests, we submit that alcohols, ethanol/methanol, make good sense in comparison to those.

And the final thing I would like to do on behalf of the Association is a few thank yous. I think that all of us committed to alcohol fuels in this country owe a big vote of thanks to Mohawk. Mohawk have been way ahead of the rest of the country in terms of what they've done. Way back in 1980-81, deciding to bite the bullet and get on this; inheriting a distillery to move into fuel alcohol production, and I'm not an expert in this area, but I gather that one of the things you don't do if you want to make a very efficient fuel ethanol plant is try to start with a distillery and modify it, because they're geared for a totally different type of economics. But they've done that; they've picked away at this thing; they've taken lots of flak, lots of negative comments on that and continued to prosper. I guess the other thanks that we have to Mohawk is that they've told the rest of us about it. In the renewable fuels movement in Canada, Mohawk has been our best banker all along in terms of assistance one way or another. And they really didn't need to do that because they had a good thing going for themselves, the market share was improving - why do they care whether the competition knows about this as well. We've appreciated that.

We appreciate the leadership that's been given by the government of Manitoba in this area, and by the provinces as well, certainly the five most western provinces. And I guess from a corn producers standpoint as well, we'd certainly like to express our appreciation to UCO, for what they're doing, and particularly to Sunoco. Sunoco seems to us to be a little bit unique among the large companies, that they have basically said that we're not going to make a full commitment, but at least we're going to give it a fair evaluation and to take a look at terms of - are the problems real; are they imaginary; how well could this structure work, and I would say from our standpoint, that we couldn't ask for more.

Finally, on behalf of the Canadian Renewable Fuels Association, I'd like to congratulate and thank the Biomass Energy Institute for the leadership they took in putting together this convention. It's been an excellent convention. Wish we maybe could have had a few more media across the back row, but we'll do that next time.

Thanks very much.



R.J. (Bob) Charles, Chairman Session 5

Maintenance System Engineer, Winnipeg Transit, City of Winnipeg

Bob Charles graduated in Aerospace Engineering from the University of Toronto in 1971 and obtained his MASc in Aerospace Engineering at Toronto in 1972. Bob is responsible for providing maintenance services in the areas of stores, building maintenance, stops and loops maintenance and engineering support.

Winnipeg Transit is one of the participating vehicle operators in the Federal Government's Methanol in Large Engines (MILE) project. Bob has been the coordinator for Winnipeg Transit since late 1985. Two Winnipeg Transit buses have been equipped since the fall of 1986, and have been operated in regular transit service since that time. Recently the methanol engines were upgraded to more current technology.

Tom Hamilton, Materials Engineer, Chrysler Canada, Windsor, Ontario.

Tom received his degree in Chemical Engineering from Queen's University in 1948. After a period in the chemical industry with another automotive manufacturer, Mr. Hamilton joined Chrysler in 1953 and assumed his present managerial position in 1971. For many years he was responsible for Canadian vendor quality activities, but most recently, has been involved with government environmental concerns such as chlorofluorocarbons and the CGSB committee regarding gasoline and alternative automotive fuels.

Chandra B. Prakash, Senior Program Engineer in the Industrial Programs Branch of Environment Canada.

Chandra holds a Ph.D. in Chemical Engineering from the University of British Columbia. He has taught at university, worked in industry, consulting, and research and development work in the United States, India, and Canada. Dr. Prakash has published more than 30 papers in the areas of heat transfer, energy and pollution control. His current responsibilities involve the assessment of technical/environmental implications of alternative fuels for motor vehicles.

Bob Schwandt, Retired Vice-President, Ethanol Sales, Staley's, Knoxville Tennessee - (now living in Decatur, Illinois).

Bob received his degree in Chemical Technology from Iowa State University in 1943. He spent the war years with the Monsanto-Wright Field NDRC solid fuel rocket repellant facility at Dayton, Ohio, and joined A.E.Staley Manufacturing Co. in 1945. Since retirement in 1986, he has been a consultant to the Ethanol and Agri business. Bob remains active in the Renewable Fuels Association and leads seminars on the effects of changes in gasoline, and ethanol/gasoline blends on auto performance.

THE ALCOHOL DILEMMA

CANADIAN POWER ALCOHOL CONFERENCE

WINNIPEG, MANITOBA

1988-10-03/04

We wish to thank Biomass Energy Institute for the invitation to speak at this conference to consider "Alcohol Fuels for Transportation". As suggested, we will be addressing Chrysler Canada's concerns regarding the use of alcohols particularly ethanol and methanol, in automotive fuels.

Chrysler vehicles are engineered to provide maximum customer satisfaction and service life with a minimum of maintenance and repair. All vehicles are designed and extensively tested for use with gasoline as has been historically mandated by fuel availability and, in approximately the past two decades, by government imposed safety, emission and fuel economy regulations. Chrysler has also lead the way in alternative fuelled vehicles in Canada by the marketing of our factory engineered and built propane units over the past seven years.

All vehicle manufacturers have an extensive data bank of gasoline related vehicle performance information. This data bank and R&D combined with competitive driving forces and vehicle

REGULATIONS HAVE FORCED THE VEHICLE MANUFACTURERS TO OPTIMIZE ENGINE AND VEHICLE PERFORMANCE FOR GASOLINE. ON THE OTHER HAND, VERY LITTLE COOPERATIVE VERIFICATION TESTING BETWEEN VEHICLE MANUFACTURERS AND FUEL MARKETERS HAS BEEN PERFORMED ON BLENDS. THE TESTS THAT HAVE BEEN PERFORMED HAVE LEFT MANY UNANSWERED QUESTIONS AND THEREFORE AN UNACCEPTABLY SMALL DATA BANK OF INFORMATION VALUABLE TO THE MANUFACTURER TO PROVIDE OPTIMIZED VEHICLE PERFORMANCE. AT THE PRESENT TIME THERE IS INSUFFICIENT INFORMATION TO ALLOW US TO ESTIMATE THE LONG TERM EFFECTS OF ALCOHOL/GASOLINE BLENDS ON POSSIBLE RECALL ACTION, LIABILITY FOR WARRANTY REPAIRS AND LEGAL SUITS.

WITH RESPECT TO ETHANOL, CHRYSLER IN 1979, WAS THE FIRST OF THE NORTH AMERICAN AUTOMOBILE COMPANIES TO SUPPORT THE USE OF GASOHOL AS AN ALTERNATIVE TO GASOLINE. UNFORTUNATELY WITH THE SHARP INCREASE IN WARRANTY, CAUSED BY DRIVEABILITY COMPLAINTS DUE TO THE RISING VOLATILITY OF GASOLINE AND THE ADDED VOLATILITY INCREASE CAUSED BY THE SPLASH BLENDING OF ETHANOL, WE WERE FORCED TO STOP RECOMMENDING ITS USE FOR SEVERAL YEARS. HOWEVER, WITH THE ADVENT OF ELECTRONIC FUEL INJECTION WE AGAIN, IN OUR 1988 AND 1989 OWNER'S MANUALS, SUPPORT THE USE OF ETHANOL. THIS DOES NOT MEAN THAT ALL OF OUR CONCERNS HAVE BEEN ANSWERED. CORROSION IN FUEL DELIVERY SYSTEMS, DEPOSITS AND OCTANE DEPRECIATION UNDER HIGH SPEED CONDITIONS ARE SIGNIFICANT CONCERNS THAT ARE BEING INVESTIGATED TO

SATISFY OURSELVES AS TO THE APPROPRIATENESS OF THIS ACTION.

IN OUR VIEW, FUEL SUPPLIERS MUST ADDRESS THE SUBJECT OF CORROSION AND DEPOSITS WITH SUCH BLENDS TO ASSURE THAT OUR MUTUAL CUSTOMERS WILL NOT SUFFER FROM FUEL RELATED PROBLEMS. AS FAR AS OCTANE DEPRECIATION UNDER HIGH SEVERITY CONDITIONS IS CONCERNED, WE ARE BEGINNING AN INTERNAL TEST PROGRAM WITH OXYGENATED FUEL BLENDS TO DETERMINE THE DEGREE OF ENGINE SATISFACTION AT OUR STANDARD CALIBRATIONS FOR APPROVED PRODUCTION ENGINES. WE ARE EXTREMELY CONCERNED ABOUT THIS PARTICULAR ISSUE BECAUSE OUR PRELIMINARY DATA SUGGESTS THAT IT MAY CAUSE TOTAL ENGINE FAILURE DUE TO IMPERCEPTIBLE KNOCK AT HIGH SPEED, THE DRIVER OR ELECTRONIC PICKUPS NOT SENSING THAT IT IS HAPPENING. WE HOPE THAT THIS INFORMATION WILL PROVIDE ENOUGH DATA TO ENABLE EM&R TO DETERMINE IF AN EXPANDED VERSION OF THIS PROGRAM IS NEEDED IN ORDER TO SATISFY THE CANADIAN GOVERNMENT SPECIFICATION BOARD MEMBERSHIP REGARDING THE POTENTIAL FOR CONSUMER PROBLEMS.

IN RESPECT TO METHANOL, WE HAVE DISCOURAGED AND CONTINUE TO DISCOURAGE THE USE OF METHANOL/GASOLINE BLENDS. IN A COOPERATIVE STUDY WITH ARCO CHEMICAL WHICH CONCLUDED IN DECEMBER 1984, FOLLOWED BY A JOINT REPORT DATED DECEMBER 1987, SEVERAL ISSUES SURFACED WHICH CONFIRMED THE NEED FOR THIS DECISION. ALTHOUGH THERE WAS A DEGREE OF DISAGREEMENT WITH ARCO AS TO THE SIGNIFICANCE OF THE RESULTS, WE FEEL THAT THE TEST PROGRAM RAISED MAJOR UNRESOLVED

CONCERNS IN SEVERAL AREAS.

THE AREAS WHICH CONCERN US ARE AS FOLLOWS:

1. DRIVEABILITY - A ONE-YEAR EVALUATION PROGRAM.

THE RESULTS OF CHRYSLER'S ANALYSIS AND THOSE OF AN INDEPENDENT CONSULTANT CLEARLY SHOWED THAT ALCOHOL/GASOLINE BLENDS DO NOT DEMONSTRATE "STATISTICAL EQUIVALENT" PERFORMANCE TO HYDROCARBON-ONLY GASOLINE. DRIVE-STALL PROBLEM RATES ON CARBURETED VEHICLES AND HESITATION/STUMBLE PROBLEM RATES ON CARBURETTED AND FUEL INJECTED VEHICLES WERE SIGNIFICANTLY INCREASED WITH 6% MEOH-3% GTBA/ GASOLINE BLEND AND OXINOL-50™. OXINOL-50™ IS A BLEND OF 4.75 VOLUME % MEOH AND 4.75 VOLUME % GTBA, THE REMAINDER BEING UNLEADED GASOLINE.

HARD-START AND HESITATION/STUMBLE PROBLEM RATES WERE SIGNIFICANTLY INCREASED IN CARBURETTED VEHICLES WITH GASOHOL WHICH WAS ALSO A PART OF THE STUDY AND CAN BE ATTRIBUTED TO SOME DEGREE TO ITS HIGHER VOLATILITY. THIS IS WHY WE INDICATE IN THE OWNER'S MANUAL, THAT IF SUCH PROBLEMS OCCUR WITH ETHANOL BLENDS, THE VEHICLE SHOULD BE OPERATED ON GASOLINE.

IN 1986 B.I. ROBERTSON DIRECTOR, PRODUCT STRATEGY PLANNING, CHRYSLER CORPORATION STATED IN REMARKS TO THE AMERICAN PETROLEUM INSTITUTE THAT DRIVEABILITY WAS THE NUMBER ONE SOURCE OF CUSTOMER DISSATISFACTION. THIS WAS BASED ON ALL OF THE IMPORTANT SURVEY METHODS CURRENTLY AVAILABLE TO US AND WAS TRUE OF ALL

MANUFACTURERS. IT WAS ESTIMATED THAT DRIVEABILITY WARRANTY FOR THE FIRST 12 MONTHS FOR ALL CARS AND TRUCKS SOLD IN NORTH AMERICA WAS APPROXIMATELY $500 MILLION PER YEAR. THIS DOES NOT INCLUDE THE COST OF AGGRAVATION OR LOSS OF CUSTOMER LOYALTY BECAUSE OF IT. ANYTHING THAT DIRECTIONALLY AFFECTS DRIVEABILITY NEGATIVELY IS A CONCERN AND NEEDS TO BE ADDRESSED.

2. EMISSIONS AT 80,000 KM

EMISSION DETERIORATION RATES DEMONSTRATED BY OXINOL-50™ FUELED VEHICLES ESPECIALLY AT HIGHER METRAGE ARE VERY DEFINITE REASONS FOR CONCERN IN VIEW OF POTENTIAL EMISSION NON-COMPLIANCE RECALLS AND THE NEGATIVE IMPACT ON AIR QUALITY. THE TEST SHOWED THAT INCREASED INTAKE VALVE AND EGR TUBE DEPOSITS WILL OCCUR. IN THE CASE OF EGR TUBE PLUGGING, OCCLUSION RATES IN EXCESS OF 75% WERE EXPERIENCED. IT IS WELL ESTABLISHED THAT THESE DEPOSITS CAN ADVERSELY AFFECT VEHICLE EMISSIONS AND PERFORMANCE.

ARCO'S REPORT RESPECTING THE EMISSION DETERIORATION FACTORS EXPERIENCED BY OXINOL-50™ FUELED VEHICLES INDICATED THAT THEY ARE DIFFERENT STATING IT IS NOT CLEAR WHETHER THEY WERE FUEL RELATED OR DUE TO VEHICLE VARIABLES. THEIR OWN DATA COLLECTED FROM TEST WORK PERFORMED AT ARCO'S HARVEY TECHNICAL CENTER WAS TERMINATED AT 32,000 KM AND DID NOT ESTABLISH ANY SIGNIFICANT DIFFERENCE BETWEEN OXINOL-50™ AND BASE FUEL. HOWEVER THE CHRYSLER/ARCO REPORT ESTABLISHES THAT A SUBSTANTIAL AMOUNT OF DETERIORATION OCCURS

BETWEEN 32,000 KM AND 80,000 KM AND A DIVERGENCE BETWEEN BASE FUEL AND METHANOL BLENDS IS EVIDENT. TRANSPORT CANADA EVALUATES EMISSION LEVEL COMPLIANCE BASED ON 80,000 KM OF OPERATION.

3. ENGINE DYNAMOMETER TESTS

THE PURPOSE OF THIS TESTING WAS TO EVALUATE COMPONENT WEAR, DEPOSIT FORMATION, AND OIL AND RUBBER SEAL DEGRADATION, WITH AN 8.2% MEOH - 2.7% GTBA/ GASOLINE BLEND. THE SIGNIFICANT OBSERVATION MADE FROM THIS TEST AS REPORTED BY THE MICHIGAN AUTOMOTIVE RESEARCH CORPORATION, WAS THE CONSIDERABLY HEAVIER DEPOSITS ON THE UNDERHEAD SIDES OF THE INTAKE VALVES AND THE CONSIDERABLY HEAVIER DEPOSITS ON THE CARBURETOR THROTTLE PLATES AND BORES OF OUR 2.2 L METHANOL BLEND ENGINE. AGAIN THE ASSOCIATION OF GREATER DEPOSIT BUILD-UP IN CRITICAL ENGINE AND CARBURETOR AREAS WITH METHANOL/GASOLINE BLENDS HAD BEEN DEMONSTRATED.

4. IN-USE FUEL SUPPLY AND EMISSION COMPONENT DURABILITY AND MATERIAL COMPATIBILITY.

THIS PART OF THE TEST PROGRAM PROVIDED THE OPPORTUNITY TO EVALUATE THE DURABILITY AND MATERIAL COMPATIBILITY OF EMISSION AND FUEL SUPPLY COMPONENTS FROM VEHICLES DEDICATED TO THE USE OF ALCOHOL/GASOLINE BLENDS IN SERVICE FOR ONE YEAR. SEVERAL AREAS OF CONCERN WERE IDENTIFIED INCLUDING REPEATED ENGINE DETONATION/ PRE-IGNITION FAILURES USING OXINOL-50™. THESE ANOMALIES WERE REPORTED BECAUSE THEY DO NOT OCCUR WITH HYDROCARBON-ONLY GASOLINE.

- Sulphonation Barrier Degradation of Polyethylene Fuel Tanks

  Polyethylene fuel tanks incorporate a sulphonation barrier to protect against fuel permeation. Directionally the tests suggest that there may be higher sulphonation losses with methanol/gasoline blends. What long term effect this trend will have on in-use evaporative emissions has yet to be determined. To address this concern, Chrysler has launched a substantial scientific research project at the University of Michigan to study the phenomenon.

- Cracks in Formed in-Tank Fuel Supply Hoses

  The fluoroelastomer hose used in conjunction with the in-tank electric fuel pump on fuel-injected vehicles is similar in design and material to that used by other automobile manufacturers. This hose developed severe deep outside cracks when immersed in alcohol/gasoline blends in a dynamic condition. As a result of this finding Chrysler released a new hose material for improved compatibility with alcohol/gasoline blends. It is evident from this work, that historic static laboratory methods are insufficient to determine adequacy of hoses in a stressed condition with these blends.

- Detachment of Electric Fuel Pump Swirl Can Reservoirs

ALL RESERVOIRS ON VEHICLES TESTED WITH METHANOL/GASOLINE BLENDS WERE EITHER LOOSE OR COMPLETELY DETACHED FROM THEIR MOUNTING ATTACHMENT AFTER ONE YEAR IN SERVICE. THIS TYPE OF FAILURE CAN RESULT IN INACCURATE FUEL LEVEL READINGS AND LOSS OF FUEL PRESSURE UNDER CERTAIN DRIVING CONDITIONS. AS A RESULT OF THIS TESTING CHRYSLER HAS RELEASED A NEW RESERVOIR MATERIAL TO PROVIDE IMPROVED COMPATIBILITY WITH METHANOL/GASOLINE BLENDS.

- LEAN OUT WITH MPI FUEL INJECTORS

ALL BOSCH MULTI-POINT INJECTORS CHECKED LEAN OUT-OF-SPECIFICATION USING METHANOL/GASOLINE BLENDS. GASOHOL ALSO PRODUCED INJECTOR LEANNESS BUT WITHIN SPECIFICATION. THIS CONDITION DID RESULT IN REPORTS OF LOSS OF PERFORMANCE AND DETERIORATED DRIVEABILITY. THIS INFORMATION HAS BEEN SUPPLIED TO THE ROBERT BOSCH COMPANY FOR FOLLOW-UP SINCE MANY DOMESTIC AND FOREIGN MANUFACTURERS USE BOSCH INJECTORS. OUR IN-HOUSE EVALUATION OF THE INJECTORS INDICATED A DEGREE OF ETCHING TO THEIR INTERNAL SURFACES WHICH COULD AFFECT THE PROPER FUEL FLOW PATTERN AND COULD BE RESPONSIBLE FOR THIS EFFECT. WE ARE CONTINUING TO INVESTIGATE THIS PHENOMENON SO THAT WE CAN MAKE CHANGES TO IMPROVE COMPATIBILITY.

DETERGENCY REQUIREMENTS ARE ALSO A CONCERN IN RESPECT TO INJECTOR PERFORMANCE AS OBSERVED BY ARCO IN THEIR REPORT -

"THIS IS AN AREA WHICH WOULD BENEFIT FROM A FULLER INVESTIGATION TO DETERMINE IF A DIFFERENT DETERGENT ADDITIVE SYSTEM SHOULD BE USED IN CONJUNCTION WITH ALCOHOL BLENDS".

o EGR TUBE PLUGGING

WE INTRODUCED THIS SUBJECT EARLIER UNDER "EMISSIONS AT 80,000 KM". TO BE MORE PRECISE THREE VEHICLES OPERATING EXCLUSIVELY ON OXINOL-50™, TWO FOR 80,000 KM AND ONE FOR 107,000 KM HAD EGR TUBES THAT WERE OCCLUDED 75%, 83% AND 100% RESPECTIVELY. EGR TUBE PLUGGING OBSTRUCTS THE FLOW OF RECIRCULATED EXHAUST GASES, RESULTS IN HIGHER NOx EMISSIONS AND MAY LEAD TO PART THROTTLE SPARK KNOCK PROBLEMS.

o ENGINE DETONATION/PRE-IGNITION FAILURES ON OUR DRIVETRAIN CYCLE

THE DRIVETRAIN CYCLE IS A STANDARD CHRYSLER DURABILITY TEST TO EVALUATE POWERTRAIN ENDURANCE IN SUPPORT OF OUR HIGH ENGINEERING STANDARDS. THE VEHICLES IN THIS PROGRAMME WERE REGULAR PRODUCTION CARS, WHOSE PRODUCTION CALIBRATION HAD BEEN PREVIOUSLY PROVEN TO PASS THIS TEST ON HYDRO CARBON-ONLY GASOLINE. ALL THREE VEHICLES OPERATING ON THIS CYCLE WITH OXINOL-50™ WERE CONSIDERED FAILURES. TWO OF THE VEHICLES EXPERIENCED A TOTAL OF FIVE PRODUCTION CALIBRATED ENGINE FAILURES DUE TO DETONATION/PRE-IGNITION. THE THIRD VEHICLE COMPLETED THE 80,000 KM REQUIREMENT BUT WAS CONSIDERED A

FAILURE BECAUSE OF AN UNRELATED CONDITION. TO REPEAT, IN RESPECT TO THE FIRST TWO VEHICLES DISCUSSED NO SIMILAR FAILURES WERE EXPERIENCED ON EQUIVALENT PRODUCTION CALIBRATED ENGINES/VEHICLES OPERATING ON THE SAME CYCLE WITH REGULAR UNLEADED HYDROCARBON-ONLY GASOLINE.

THE DRIVETRAIN DETONATION/PRE-IGNITION FAILURES ARE THE RESULT OF THE COMBINED EFFECTS OF FUEL/AIR ENLEANMENT, MALDISTRIBUTION AND OCTANE DEPRECIATION AT HIGH SPEED, HIGH-LOAD CONDITIONS WITH OXINOL-50™. THIS IS BEING STUDIED AS INDICATED EARLIER.

5. STATIC LABORATORY MATERIAL COMPATIBILITY TESTS

THE TESTS FOR MATERIAL COMPATIBILITY WERE CONDUCTED IN TWO PARTS - (A) FOR RUBBER AND PLASTIC MATERIALS AND (B) FOR METALLIC MATERIALS. THERE WERE TEN (10) RUBBER MATERIALS AND TWELVE (12) PLASTIC MATERIALS TESTED, ALL OF WHICH WERE UTILIZED IN THE FUEL SYSTEM. ELEVEN (11) METAL MATERIALS REPRESENTATIVE OF THEIR RESPECTIVE USES IN THE FUEL SYSTEM WERE TESTED. WE ARE NOT SUGGESTING THAT THIS TEST PROGRAMME IS REPRESENTATIVE OF ALL SUCH MATERIALS.

WITH RESPECT TO THE RUBBER AND PLASTIC MATERIALS, THE RESULTS SUGGESTED THAT LOW-LEVEL ALCOHOL/GASOLINE BLENDS MAY BE COMPATIBLE IN A CONTROLLED LABORATORY ENVIRONMENT BUT NOT NECESSARILY UNDER ALL CONDITIONS ENCOUNTERED BY VEHICLES. IN THE CASE OF THE FUEL

HOSES UNDER IMMERSED DYNAMIC STRESS, STATIC LABORATORY TESTING WAS INSUFFICIENT TO PREDICT IN-USE CAPABILITY.

THE RESULTS OF THE METAL TESTS AFTER ONE YEAR OF CORROSION TESTING SUGGEST THAT LOW-LEVEL METHANOL/GASOLINE BLENDS WITHOUT WATER CONTAMINATION MAY BE COMPATIBLE WITH METALLIC FUEL SYSTEM MATERIALS IN A CONTROLLED LABORATORY ENVIRONMENT BUT NOT NECESSARILY UNDER ALL CONDITIONS ENCOUNTERED BY VEHICLES.

CONCLUSION:

AS YOU CAN APPRECIATE, BASED ON THE EXTENSIVE NATURE AND SCOPE OF THIS TEST PROGRAMME, OUR CONCERNS ARE SEVERAL, ENCOMPASSING OCTANE DEPRECIATION UNDER HIGH SEVERITY CONDITIONS, CORROSION, DEPOSITS, AND MATERIALS COMPATIBILITY WHEN DEALING WITH ALCOHOL/GASOLINE BLENDS. WE REALIZE THAT OUR OLDER VEHICLES ARE NOT COMPATIBLE WITH THESE BLENDS. HOWEVER WE ARE ATTEMPTING TO MAKE NEW CARS AS COMPATIBLE AS POSSIBLE. OUR SUPPLIERS ARE REQUIRED TO DESIGN THEIR COMPONENTS TO BE METHANOL COMPATIBLE, BUT OTHER ISSUES SUCH AS OCTANE DEPRECIATION UNDER HIGH SEVERITY CONDITIONS AND CORROSION AND DEPOSIT CONTROL ARE STILL MAJOR CONCERNS. CHRYSLER CANADA IS AN ACTIVE MEMBER OF THE CGSB GASOLINE AND ALTERNATIVE FUELS COMMITTEE IN ITS TASK TO DEVELOP FUEL SPECIFICATIONS. AS A MANUFACTURER OF AUTOMOTIVE VEHICLES OUR PRIME CONCERN IS SATISFIED CUSTOMERS AND IT IS WITH THIS IN MIND THAT OUR PRESENT OWNER'S MANUAL FUEL STATEMENT IS ISSUED. WE ARE WILLING

TO WORK WITH ALL PARTIES TO ADDRESS THE CONCERNS WE HAVE MENTIONED IN AN EFFORT TO DEVELOP ALCOHOL/GASOLINE BLEND SPECIFICATIONS THAT WILL ADEQUATELY RESOLVE OR MAKE THESE ISSUES MANAGEABLE.

VEHICLE UPGRADING TO ACCOMMODATE ALCOHOLS IS A COST INCREASE ITEM. OUR EXPERIENCE WITH THE PROPANE PROGRAMME HAS TOLD US THAT IF EVERY REQUEST TO ACCOMMODATE ALTERNATIVE FUELS WAS INCORPORATED THE OVERALL COST WOULD BE EXORBITANT AND COULD LIMIT OUR ABILITY TO TAKE ADVANTAGE OF FUTURE TECHNOLOGY OR RESPOND TO NEW GOVERNMENT REGULATIONS.

IN THE FINAL ANALYSIS, IT IS THE CUSTOMER WHO MUST PAY FOR PROVIDING OPTIMIZED VEHICLE PERFORMANCE FOR BLEND COMPATIBILITY. HOWEVER, G.E. ALLARDYCE, OF OUR CERTIFICATION AND REGULATORY PROGRAMMES DEPARTMENT, STATED AT A 1986 PRESENTATION TO THE WASHINGTON CONFERENCE ON ALCOHOL, "CHRYSLER WILL CONTINUE TO MAKE EVERY REASONABLE EFFORT TO DESIGN, TEST AND BUILD VEHICLES TO ACCOMMODATE AND WITHSTAND THE EFFECTS OF BLENDS TO THE EXTENT IT IS POSSIBLE TO DO SO".

THE LAST SUBJECT WE WISH TO ADDRESS IS NEAT OR NEAR-NEAT METHANOL (M85). CHRYSLER FEELS STRONGLY, AND HAS MADE PUBLIC ITS CONVICTION THAT METHANOL REPRESENTS A SIGNIFICANT OPPORTUNITY AS AN ALTERNATIVE FUEL IN THE FUTURE. THESE VEHICLES WOULD BE FULLY OPTIMIZED FOR DEDICATED METHANOL USE, WITH HIGHER COMPRESSION RATIO AND OTHER FEATURES THAT INCREASE EFFICIENCY. THE GREATEST PRESSURE

TO INTRODUCE ALCOHOL FUELS, WE BELIEVE, WILL RESULT FROM ENVIRONMENTAL CONCERNS. THE ONGOING ISSUE OF COMPLIANCE WITH OZONE RELATED NATIONAL AIR QUALITY STANDARDS, CONTINUING CONCERN ABOUT ACID RAIN, AND THE GENERAL CONCERN FOR AIR QUALITY WILL ALL SERVE TO INCREASE THE NUMBER OF DEMONSTRATION FLEETS AND ULTIMATELY WIDER AND WIDER FLEET USAGE OF ALCOHOL, MOST PROBABLY METHANOL.

THE ULTIMATE TEST WILL BE THE VIABILITY OF METHANOL FUEL VEHICLES IN NON-INCENTIVE APPLICATIONS OF COMMERCIAL SERVICE SUCH AS BUSES AND TAXIS, WHEN THE PREVAILING SUPPLY OF METHANOL IS FULLY UTILIZED AND NEW METHANOL CAPACITY MUST BE PROVIDED.

1988-09-12

T.M. HAMILTON

ENVIRONMENTAL ISSUES RELATED TO THE USE OF ALCOHOLS AS MOTOR VEHICLE FUELS

by

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ABSTRACT

This paper provides an overview of environmental issues and addresses the environmental implications of exhaust and evaporative emissions from motor vehicles using low level alcohol-gasoline blends and neat alcohol. In general, the use of alcohol fuels reduces carbon monoxide and hydrocarbons in the exhaust emissions as compared to gasoline; emissions of oxides of nitrogen remain about the same for low level blends but decrease for neat alcohol; alcohol and aldehyde emissions increase. The evaporative emissions from blends are comparable to those from gasoline if the Reid vapour pressures of the two fuels are closely matched. The specific implications of these vehicle emissions on the greenhouse effect, acid rain, ground level ozone, carbon monoxide, and toxics are discussed.

INTRODUCTION

Transportation has played a central role in the social and economic development of Canada. As the population continues to grow and prosper and as industrial activities and trade increase the volume of personal travel and the movement of goods will increase further.

At the present time the transportation sector is a major consumer of non-renewable petroleum resources accounting for approximately 60% of the present oil demand. Any increases or decreases in the use of petroleum based fuel by motor vehicles will therefore affect the national petroleum requirements and the potential need for imports.

The transportation sector is also a major source of atmospheric pollution. At the present time, for example, transportation is responsible for about 66% of emissions of both oxides of nitrogen and volatile organic compounds into the atmosphere from all sources. If petroleum based fuels will be used to meet increases in transportation energy demand, an increase in the emissions of atmospheric pollution from this sector will occur.

In this connection it should be noted that in Canada the protection of the environment is seen by the public as a high priority issue even more important than the state of the economy and the federal deficit. It tends to be a non-partisan political issue, and often, although there are changes in governments, there is concurrence and continuance in environmental programs and initiatives. The protection of the environment has developed from a minority fringe issue of the sixties to a majority mainstream issue of the eighties.

Consequently, concern about dependence on imported petroleum and atmospheric pollution are motivating government and industry to search for alternative fuels. Non-petroleum derived alcohols, especially methanol and ethanol, are the most promising candidates for use as alternative automobile fuels in the near future (1). *

This paper provides an assessment of emissions performance of methanol and ethanol in low level alcohol-gasoline blends and in their neat form in automobiles equipped with spark ignition engines. Other environmental, health, and safety issues related to the handling of alcohol-gasoline blends, fuel spills, groundwater contamination, flame visibility, flammability, etc. are not addressed in this paper.

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* Numbers in parenthesis designate reference given at the end of the paper.

ENVIRONMENTAL ISSUES

The environmental issues and implications of methanol, ethanol and alcohol-gasoline blends used as alternative automobile fuels relate not only to the ultimate use of these fuels but also to their manufacture and to their distribution from plant to retail level.

In general, the environmental implications of manufacture and distribution can be dealt with routinely by observing established rules and procedures. Only if process materials or wastes generated are toxic or potentially hazardous to human health and the environment specific control measures have to be instituted.

Significant environmental issues relate to fuel use. Automotive emissions degrade urban air quality, contribute to the greenhouse effect, acid rain and ground level ozone, and add toxic materials such as diesel particulates, lead, benzene, aldehydes and dioxins to the air.

Rising global temperatures - the greenhouse effect - are attributed to atmospheric pollutants known as the greenhouse gases. These gases, which include carbon dioxide, methane, ozone, nitrous oxide and a variety of synthetic chemicals absorb a larger amount of thermal radiation emitted from the earth's surface causing the atmosphere to become warmer. As a consequence a new climatic equilibrium is established with higher ambient temperatures.

The major precursors to acid rain in Canada are sulphur dioxide emissions from smelters and fossil fuel powered electric generating stations and emissions of oxides of nitrogen from motor vehicles. These pollutants react in the atmosphere to form acids which, when deposited on land or in lakes as acid rain, lead to chemical changes that affect all plants and animals in the ecosystem.

When oxides of nitrogen and hydrocarbons react in the presence of sunlight they produce ground level ozone which harms human health and causes crop damage. About one quarter of Canada's population is exposed to episodes of ozone in summer; crop damage is estimated at forty million dollars annually. Ozone is a problem of particular concern in the lower mainland of British Columbia, the Windsor-Québec corridor, and the Maritimes.

As hydrocarbons are also released by fuel evaporation, fuel volatility has a major effect on ground level ozone. Hence, the federal and provincial governments and industry are cooperating to assess the effectiveness of reduced fuel volatility.

With the phase-out of lead form gasoline the petroleum industry is being challenged to develop environmentally safe alternative means of octane enhancement. This basically precludes increasing the aromatics content of gasoline, particularly of benzene which is a known carcinogen.

Of particular importance to alternative fuels in the future will be the Canadian Environmental Protection Act (CEPA). This Act has as its focus a life-cycle management approach to toxic chemicals and will be administered to emphasize the complementary strategies of anticipation and prevention. We now accept that prevention is not only preferable to cleanup but more cost effective. CEPA embodies an ecosystem vision of environmental protection encompassing air, land, water, all layers of the atmosphere and all organic and inorganic matter and living organisms. The Act recognizes the importance of environmental protection and issues a strong policy statement linking protection of the environment from the effects of toxic substances with the life and health of Canadians. Above all the Act improves the federal government's ability to control the release of toxic substances into the environment. It has also provisions which permit Environment Canada to specify fuel composition as it applies to the environment.

Hence it is essential that, in addition to the technical and economic elements, the environmental issues and implications be assessed, addressed and taken into account as all alternative fuels, fuel modifications and fuel additives, including alcohols and alcohol-gasoline blends, are introduced into the Canadian transportation fuel market.

ROLE OF ALCOHOLS AS TRANSPORTATION FUELS

Alcohols can be used as transportation fuels in their neat form or as components in blends with gasoline. The following three categories are generally used to classify alcohol fuels:

(i) Low Level Blends.

The alcohol content in low level blends is generally not more than 10% by volume. These blends can be used in place of gasoline in automobiles equipped with spark ignition engines.

(ii) High Level Blends.

The alcohol content in high level blends is generally more than 15% by volume and may be as high as 60% by volume. Engines designed to run on gasoline cannot maintain good driveability with high level blends mainly because of increased fuel leaning effect. Retrofitting of existing cars is possible, but only purpose-built cars can fully utilize the properties of high level blends. In North America there is no incentive to use these blends, and hence these are not discussed in this paper.

(iii) Neat Alcohols

Neat alcohols are defined as fuels containing a minimum of 85% by volume alcohol the remaining being gasoline hydrocarbons. Significant changes in engines and fuel systems are needed for reliable operation on these fuels. Large-scale use of neat alcohols has taken place in Brazil (ethanol) and on small scale in California (methanol).

It should be noted in particular that, in regard to all alcohol containing gasolines, systems which allow vehicles to operate on alcohol, gasoline, or variable mixtures of the two fuels are being developed. An essential part of these flexible-fuel vehicles is a sensor unit which measures the alcohol/gasoline ratio and signals the computer to adjust the fuel supply rate (2).

SOME IMPORTANT PROPERTIES OF ALCOHOL FUELS

Blending methanol and/or ethanol with gasoline results in significant changes in fuel properties as well as in combustion and emissions characteristics. The property changes of particular interest include octane enhancement, volatility, solubility and phase separation.

(i) Octane Enhancement.

Gasolines with high octane rating resist auto-ignition and detonation (knock) of the air-fuel mixture in the motor vehicle engine. As a result they make it possible to use spark ignition engines with high compression ratio thereby achieving high fuel economy and output.

The measure of anti-knock properties of the fuel is expressed as two numbers: the Research Octane Number (RON) is a measure of the ability of the fuel to resist knock at low speed and low load and the Motor Octane Number (MON) is an equivalent measure at high speed and high load. In North America this fuel quality is also expressed by the Anti-Knock Index (AKI) which is the arithmetic mean of the RON and MON. Engines are designed to operate on a minimum octane number fuel below which engine performance and longevity are seriously affected.

While certain organic lead compounds have been the prime octane enhancers in gasoline in the past, they are being phased out for health reasons. The elimination of lead in gasoline can be offset by adding other octane enhancers, including alcohols, or by modifying the refinery process. Octane enhancement diminishes as the molecular weight of the alcohol is increased. The octane rating of methanol, for example, is about 110 as compared to the minimum octane requirements of 88 and 92 for regular and premium gasolines respectively. A typical gasoline blend containing five percent by volume methanol has an octane rating of about two numbers higher than the gasoline in which it was blended (3). However, when blended with gasoline, methanol raises the RON much more than the MON. This can result in a gasoline with a high AKI which may not perform as well at high engine speeds as might be expected.

The high octane values of neat alcohols permit significant increases in compression ratio and/or spark advance resulting in increased engine power and efficiency. The higher latent heats of alcohols provide fuel-air charge cooling and density increases with resulting improved volumetric efficiencies. Taken together, these factors can be exploited to allow the use of smaller engines in place of larger ones at the same performance levels (4).

(ii) Volatility.

Volatility determines the amount of fuel vapourized under a given set of temperature conditions. Methanol and ethanol have low volatilities in comparison with gasoline. However, when methanol and/or ethanol are added to gasoline they form azeotropic and non-ideal mixtures with much higher vapour pressure, commonly expressed as the Reid Vapour Pressure (RVP), than gasoline and consequently higher volatilities.

The magnitude of deviation from ideality generally decreases with higher boiling-point alcohols. The blending of alcohols with gasoline also changes the shape of the distillation curve. The RVP and the distillation curve affect the evaporative and exhaust emissions (5,6) as well as the fuel's cold starting, driveability and vapour locking characteristics (7,8).

The RVP of an alcohol-gasoline blend can be matched with that of base gasoline by removing butane or other volatile components from the blend's gasoline part. In addition, it is also possible to match the distillation curves of a blend and base gasoline by more complex blending procedures of the blend's gasoline part which involve adjusting its various hydrocarbon components.

The low volatility of neat alcohols can cause cold-start problems. Due to its high latent heat methanol demands over seven times the heat addition of gasoline for complete vapourization. Consequently, the warmup period is extended and driveability during this phase of engine operation is poor. The addition of small amounts of gasoline hydrocarbons can alleviate cold-start and driveability problems.

(iii) Solubility and Phase Separation

The solubility of methanol in gasoline is limited and is dependent upon gasoline composition and temperature. Methanol has a higher solubility in aromatic hydrocarbons than in paraffins, with naphthenes and olefins being somewhat intermediate. Increasing temperatures also improve the solubility.

A further problem of immiscibility is the low water tolerance of the alcohol-gasoline mixture which results from the tendency of methanol to partition with water. This water may be introduced as a contaminant in storage tanks and transfer lines, as well as through condensation of atmospheric water inside the vehicle's fuel tank as its temperature cycles through the ambient dew point. Poor water tolerance can result in the formation of two layers, the upper one hydrocarbon rich and the lower one methanol-water rich. The water tolerance of methanol-gasoline is also dependent upon gasoline composition, temperature and methanol content.

To overcome these difficulties the better solubility of the higher alcohols in gasoline is utilized. The higher alcohols, including ethanol, have a co-solvency effect on methanol and are used to improve the water tolerance of low level methanol-gasoline blends.

Neat alcohols containing moderate amounts of hydrocarbons can absorb considerable amounts of water. Phase separation problems will, therefore, not occur with the amounts of water condensate that are known to accumulate in gasoline distribution systems.

EMISSIONS FROM VEHICLES USING ALCOHOL FUELS

Motor vehicles cause air pollution through exhaust and evaporative emissions. Exhaust emissions result from fuel combustion in the vehicle engine. Evaporative emissions occur from the vehicle fuel system, when handling fuel and when refueling motor vehicles. The environmental impacts depend upon the quantity and characteristics of undesirable substances contained in these emissions.

The emissions include carbon dioxide (CO_2); the regulated pollutants carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NOx); and the presently unregulated pollutants such as aromatics, aldehydes and alcohols.

The different categories of alcohol fuels should be treated separately in assessing exhaust and evaporative emissions.

(i) Low level Alcohol-Gasoline Blends.

Blends can and have been used in existing spark ignition engines. In a general way, the effect of adding alcohol to gasoline on the regulated exhaust emissions can be predicted on the basis of the physical properties of the blend. Low level alcohol-gasoline blends contain more oxygen. The leaning effect of alcohol results in a decrease in CO emissions and relatively smaller decrease in HC emissions. The change in NOx emissions are small and may increase or decrease depending upon the air-fuel ratio in the engines. However, aldehyde and alcohol emissions increase.

Fuel metering devices on vehicles such as carburetors or fuel injectors (without an oxygen sensor or with an oxygen sensor but operating in the "open loop" mode where the sensor is not functional) usually meter fuel and air volumetrically. Thus the oxygen in the fuel results in less fuel and more total oxygen reaching the engine for fuel combustion. If the initial mixture when using gasoline is rich of stoichiometric, this enleanment results in reduced exhaust CO and HC but causes an increase in NOx emissions (Figure 1).

A closed-loop vehicle with the oxygen sensor in control of the engine will try to compensate for the oxygen present in the fuel by increasing the fuel flow until stoichiometry is achieved. If its fuel system has the necessary range of control, such a vehicle experiences little or no enleanment due to the blend for those portions of vehicle operation when the oxygen sensor is functioning and in control of the engine. Thus one expects a smaller absolute reduction in exhaust CO and HC emissions from vehicles with oxygen sensors. It should be noted, however, that a closed-loop vehicle produces most of its CO during the occasional open-loop modes of operation.

Some of the newer closed-loop vehicles are equipped with "adaptive learning". Properly functioning vehicles with adaptive learning continuously adjust their open-loop fuel calibrations based on the most recent period of closed-loop operation. Thus they can in theory compensate at least partially for fuel-caused enleanment, even when the oxygen sensor is not in control, such as during cold starts and heavy accelerations. They may also not run as rich in failure modes as simpler closed-loop vehicles. These vehicles are expected to have even lower exhaust CO and HC reductions from oxygenated blends.

Higher RVP's of low level alcohol-gasoline blends (which are not matched for volatility) also cause increases in exhaust emissions. For example, an increase in RVP of 1 psi results in a CO increase in the range of 3.1 to 7.6 percent (depending on the type of vehicle) at an ambient temperature of 24°C. The corresponding increase in the exhaust HC emissions varies between 1.8 to 3.7 percent (9).

Emissions from motor vehicle engines are sensitive to many operating conditions, including speed, load, ambient temperature and fuel composition. The most commonly used method for determining exhaust emissions from motor vehicles are based on the Federal Test Procedure (FTP) developed by the U.S. EPA (10) which employs a transient urban cycle at a minimum temperature of 68°F (20°C).

Changes in emissions from vehicles operating on low level alcohol-gasoline blends (up to 5% methanol plus cosolvent, and up to 10% ethanol) relative to gasoline are summarized in Tables 1 and 2 for exhaust and evaporative emissions respectively. The values are based on the published data (11, 12).

The exhaust emissions trends shown in Table 1 indicate that low level alcohol-gasoline blends reduce the CO emissions by 15 to 40% in older vehicles without catalysts and with oxidation catalysts, and by 5 to 20% in newer vehicles equipped with three-way catalysts using closed-loop and/or adaptive learning. The total HC emissions for low level alcohol-gasoline blends are 5 to 15% lower in the case of older vehicles and in the 5% range for newer cars. The effect of alcohol blends on NOx emissions is small. The alcohol and aldehyde emissions for all types of vehicles increase substantially. Formaldehyde, which is the major component of aldehyde emissions, is suspected to be a carcinogen. The three-way catalytic converters which are in use on all new vehicles in Canada starting with the 1988 model year are very efficient in reducing aldehyde emissions.

The evaporative hydrocarbon emissions trends, shown in Table 2, consist of hot soak and diurnal emissions. Hot soak emissions occur during the period immediately following engine shut-down, i.e. at the end of each vehicle trip. These emissions originate from both the fuel metering systems and from the fuel tank, and are greater for carbureted vehicles than for vehicles with fuel injection. Diurnal emissions consist of hydrocarbons both evaporated and displaced form the vehicle's fuel tank, as the vehicle tracks the diurnal swing in ambient temperatures. Each day, as the fuel in the tank and the vapour above the fuel heat up, more of the liquid fuel evaporates and the vapour itself expands causing hydrocarbons to be released into the atmosphere. The most commonly used method for determining evaporative emissions from vehicles employs the Sealed Housing Evaporative Detemination (SHED) test with a diurnal temperature swing of 60° to 84° F (16° to 29° C).

The United States Environmental Protection Agency's (U.S. EPA) motor vehicle fleet model MOBILE 3 and Environment Canada's model MOBILE 3C, which is a modified version of the U.S. model, use a single emissions rate in grams per mile by assuming that each vehicle makes 3.05 daily trips totaling 31.1 miles per day. Hence 3.05 incidences of hot soak emissions are assumed for every diurnal emission cycle. In reality the relative number of hot soak and diurnal emissions vary with vehicle age, locality of operation and driving patterns. In addition to these factors, some of which can be modeled by MOBILE 3C, MOBILE 4 will take ambient temperature and volatility into account.

The evaporative emissions increase with increasing fuel volatility as a non-linear function of RVP. Thus alcohol-gasoline blends with unadjusted RVP produce higher evaporative emissions.

Addition of methanol and/or ethanol to gasoline changes the distillation curve of the fuel and, in particular, increases the quantity evaporated at 160°F (71°C). This increase at 160° F has been shown to result in an increase in hot soak evaporative emissions even if the RVP of the alcohol blend is kept at the same level as gasoline (13).

Another important phenomenon which increases the fuel volatility is called "comingling". It refers to the mixing of an alcohol-gasoline blend and gasoline in the vehicle fuel tank whenever consumers switch from one fuel type to the other when refueling their vehicles at different service stations. Due to the non-linear increase of fuel volatility with alcohol concentrations, mixing of gasoline and alcohol-gasoline blend of the same RVP always results in a mixture with a higher RVP. Studies at General Motors, for example, have shown that mixing four parts of a gasoline with an RVP of 9 psi with one part of a 5% methanol plus 95% gasoline blend with the same RVP results in blend with an RVP of 10.7 psi (14).

The evaporative hydrocarbon emissions values in Table 2 indicate the importance of controlling the volatility of low level alcohol-gasoline blends by maintaining the RVP at the same level as for gasoline. Direct addition of 10% ethanol to a finished gasoline (splash blending) raises the RVP of the blend by approximately 1.0 psi while the corresponding increase in RVP for methanol plus cosolvent addition (typically 5% methanol plus 3% ethanol) to gasoline is about 2.0 to 2.5 psi. Thus splash blending of methanol plus cosolvent with gasoline causes much higher evaporative hydrocarbon emissions than shown in Table 2. The increase in RVP also increases the exhaust HC emissions.

(ii) Neat Alcohols.

Most of the published work on emissions from neat alcohol fuels relate to methanol. Relatively little attention has been given to neat ethanol in North America because of its limited supply and high cost of production. In general, however, the characteristic emissions from ethanol tend to fall between those of methanol and gasoline.

The majority of recently reported investigations confirm that significant reductions of some regulated emissions are attainable when neat alcohols are used as automotive fuels. CO emissions, however, tend to be essentially equal to those from gasoline when the engine is operated at constant equivalence ratio (4, 15, 16).

Methanol is an inherently low producer of NOx whose production in the combustion process is temperature dependent and declines as the temperature decreases. In the work reported by Pefley et al (15) NOx emissions were reduced approximately 30% by a change to neat methanol from Indolene. Menard et al (16) observed similar reductions and noted that even when an engine has been modified for a considerably higher compression ratio (CR) of 13, which normally aggravates NOx emissions, the NOx emissions were about the same as those produced by gasoline at the original 8.2 CR.

As methanol has wider flammability limits, it can be burned at leaner equivalence ratios than gasoline without lapsing into misfire and other lean combustion problems (contigent upon assuming equally good mixture preparation). Further CO and NOx reductions may be attained by operation in this fuel-lean regime. As the lean misfire limit is approached, however, unburned fuel emissions increase.

The effect of methanol on unburned fuel (UBF) emissions has, until fairly recently, been somewhat ambiguous. The UBF emissions of gasoline are essentially all hydrocarbons while those from neat methanol are virtually all methanol or other oxygenates (17). One of the crucial factors leading to early conflicts in the data is that emissions analysers, such as flame ionization detectors (FID), do not respond fully to oxygenates and thus under-report methanol UBF.

A recent approach to resolving these problems has been to report unburned fuel as unburned carbon, not including CO. On this basis, methanol appears to offer an advantage over gasoline in UBF emissions.

The catalyst conversion efficiency for methanol unburned carbon emissions is reported to be as good as for gasoline carbon emissions (15).

Alcohol fuels, particularly methanol, produce aldehydes. Aldehydes are photochemically reactive and highly irritating to mucous membranes. As they are not a major constituent in gasoline exhaust emissions, they are not currently regulated. Aldehyde emissions from neat methanol (primarily formaldehyde) may be up to five times higher as compared to emissions form gasoline and hence the widespread use of alcohol fuels would likely require specific controls. Fortunately, three-way catalytic converters are effective in controlling aldehyde emissions.

Low ambient temperatures, which are of particular relevance in Canada, increase the CO and HC exhaust emissions significantly while NOx emissions are not affected. The relationship between ambient temperature and aldehyde emissions has not yet been fully evaluated.

Relatively little research has been performed on vehicle evaporative emissions from neat alcohols. Most work in this area has concentrated on alcohol-gasoline blends. There is some limited data to indicate that neat methanol fueled vehicles can meet the current U.S. evaporative emissions level of 2.0 grams per test, based on the carbon emissions standards, at least early in their service life.

One of the most commonly needed statistics for air quality models is the ratio of various types of hydrocarbons. Gold and Moulis (18) have summarized all the available emissions data from light-duty methanol fueled vehicles. For the exhaust emissions of properly functioning vehicles, i.e. those meeting CO and NOx standards, the ratio of methanol to non-oxygenated hydrocarbons to formaldehyde was found to be 1.00:0.278:0.0884. The corresponding ratio for the evaporative emissions was 1.00:0.305:0.068. These data indicate that for both exhaust and evaporative emissions non-oxygenated hydrocarbons are emitted at much higher levels than their proportion in the fuel. Reducing the quantities of gasoline blended into methanol is therefore expected to enhance the environmental benefits of alcohol fuel from both a photochemistry and a toxicological point of view. This approach may be limited by driveability considerations.

In recent years the possibility has been raised that the widespread use of neat methanol may give rise to a new emissions concern. Japanese research has demonstrated that methanol and nitrogen oxides can react in the atmosphere to form methyl nitrite (CH_3ONO) (19). This is toxic to laboratory animals; however, its toxicity to humans has not been established. Exposure to ultraviolet radiation will subsequently convert methyl nitrite to methyl nitrate (20).

ENVIRONMENTAL IMPLICATIONS OF ALCOHOL FUELS

The use of alcohol fuels instead of gasoline results in changes in the quantity and composition of exhaust and evaporative emissions from automobiles. Hence the widespread introduction of alcohols as motor vehicle fuel will have a number of important environmental implications. The effects on global warming (greenhouse effect), acid rain, ground level ozone, carbon monoxide, and air toxics are discussed below and summarized in Table 3.

(i) Greenhouse Effect

The carbon content of gasoline, methanol and ethanol is approximately 85 %, 37.5 % and 52% respectively; the corresponding lower heating values are approximately 44000, 20000 and 27000 kilojoules/kilogram. Thus for a given power output approximately similar quantities of CO_2 are emitted.

Control of motor vehicle CO_2 emissions by converters or other such systems is impractical. Any attempt by the transportation sector to reduce CO_2 must therefore focus primarily on the imposition of greater fuel economy requirements and the more efficient use of fuels.

It is necessary also, in this connection, to consider the nature of the feedstocks of these three fuels from the point of view of "recycling" of the carbon. In the combustion of petroleum and natural gas derived transportation fuels the carbon is "mined" and the CO_2 emissions from these fuels increase the carbon content of the atmosphere. With biomass derived fuels, if feedstock production equals consumption, the carbon is merely being cycled between terrestrial biota and the atmosphere. However, if agricultural lands, forests or other ecosystems are cleared or harvested more rapidly than they can be regrown, the standing biomass is, in effect, being mined and the benefits of carbon recycling are lost (21). Reference is also made to the extensive world literature on this subject and the role of the Atmospheric Environment Service of Environment Canada.

(ii) Acid Rain

As the NOx output from gasoline and alcohol-gasoline blends is approximately similar their contribution to acid rain generation is about the same. However, the use of neat alcohols reduces NOx emissions and its contribution to acid rain is therefore less.

(iii) Ground Level Ozone

To assess the ozone forming potential of low level alcohol-gasoline blends it should be realized that blends emit higher quantities of aldehydes and alcohol in exhaust emissions, and that a portion of evaporative emissions from blends consists of alcohol. Various studies have indicated that methanol is less photochemically reactive than typical gasoline hydrocarbons, whereas ethanol's reactivity is comparable to butane and toluene (22). Based on the U.S. EPA modeling and smog chamber data methanol-gasoline blend vapour is estimated to be about 12 to 15% less reactive than gasoline vapour (6). On the other hand, formaldehyde is about three times more reactive than typical gasoline hydrocarbons. Thus on an overall basis the ozone forming potential of low level alcohol-gasoline blends can be assumed to be about the same as of gasoline.

Based on the proposed EPA carbon based organic emissions standards for methanol fueled vehicles the emissions of volatile organic compounds from neat alcohol fuels will be about 35% lower as compared to gasoline. The impact on ozone reduction in specific areas will vary depending upon the nature of hydrocarbons, HC/NOx ratio and atmospheric conditions.

(iv) Carbon Monoxide

The reduction of CO emissions when using alcohol fuels is recognized.

(v) Toxics

The emission of certain substances in motor vehicle emissions including benzene, other aromatics and aldehydes is of concern from environmental and health perspectives and hence could be potential candidates for regulation under CEPA.

SUMMARY

There are substantial environmental benefits resulting from the use of alcohol-gasoline blends and neat alcohol through reductions in carbon monoxide and hydrocarbon emissions. However, there is evidence that the combustion of these fuels results in increased emissions of aldehydes which are suspected to be carcinogenic but are not regulated at present. The new Canadian vehicle emissions standards which came into effect on September 1, 1987, will result in all new automobiles being equipped with three-way catalytic converters which are very efficient in reducing aldehyde emissions. Hence aldehyde emissions from these new vehicles will be lower even when operating on blends and neat alcohol as compared to older vehicles operating on gasoline.

A significant environmental issue relates to evaporative emissions. If the volatility of an alcohol-gasoline blend is higher than that of gasoline it would result in substantially higher evaporative emissions, which in turn would cause and aggravate ground level ozone problems. Consequently, increasing the volatility of these fuels would make them environmentally detrimental.

In summary, there is a substantive role for fuel alcohols in the Canadian transportation sector. Government and industry must cooperate to ensure that the environmental benefits and potential problems are assessed, addressed and taken into account prior to fuel alcohols entering widespread use in this market.

ACKNOWLEDGEMENT

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TABLE 1

EXHAUST EMISSIONS FROM LOW LEVEL
ALCOHOL-GASOLINE BLENDS

10% Ethanol or 5% Methanol plus Cosolvent, typically 3.7% by weight Oxygen

	Percent Change from gasoline of same RVP		
TECHNOLOGY	Non-Catalyst	Oxidation Catalyst	Three-Way Catalyst
POLLUTANTS			
CO	-(15 to 40)	-(15 to 40)	-(5 to 20)
HC	- (5 to 15)	- (5 to 15)	up to - 5
NOx	+ (3 to 5)	+ (3 to 5)	up to + 3
Alcohol	+ 1200	+ 800	+ 150
Aldehyde	+(50 to 100)	+(50 to 100)	+(50 to 100)

TABLE 2

EVAPORATIVE EMISSIONS

	Percent Change in Evaporative Hydrocarbon Emissions relative to Gasoline *	
VAPOUR PRESSURE	Matched RVP	1.0 psi margin
10 % Ethanol Blend		
Carbureted	- (1.0 to 1.6)	+ (24 to 55)
Fuel Injected	- (1.6 to 2.0)	+ (53 to 76)
1990 Mix	- (1.2 to 1.8)	+ (33 to 64)
Methanol/Cosolvent Blend		
Carbureted	- (3.5 to 5.4)	+ (21 to 47)
Fuel Injected	- (5.4 to 6.7)	+ (47 to 65)
1990 Mix	- (4.1 to 6.0)	+ (29 to 55)

* This includes the RVP effect on both diurnal and hot-soak emissions. The minima correspond to current certification fuel RVP (9.0 psi) and the maxima to current in-use RVP (averaging near 11.5 psi for ASTM Class C).

TABLE 3

IMPLICATIONS OF ALCOHOL FUELS ON
ENVIRONMENTAL ISSUES
AS COMPARED TO GASOLINE

Environmental Issues	Effects By	
	Blends (Matched RVP)	Neat Alcohols
Greenhouse Effect	Marginally positive * - if carbon is recycled	Positive - if carbon is reclycled None - if carbon is "mined"
Acid Rain	Insignificant	Positive
Ground Level Ozone	Insignificant	Positive
Carbon Monoxide	Positive	Positive
Air Toxics	Positive - HC including aromatics Negative - aldehydes, alcohols	Positive - HC including aromatics Negative - aldehydes, alcohols

* Positive refers to a reduction; negative refers to an increase.

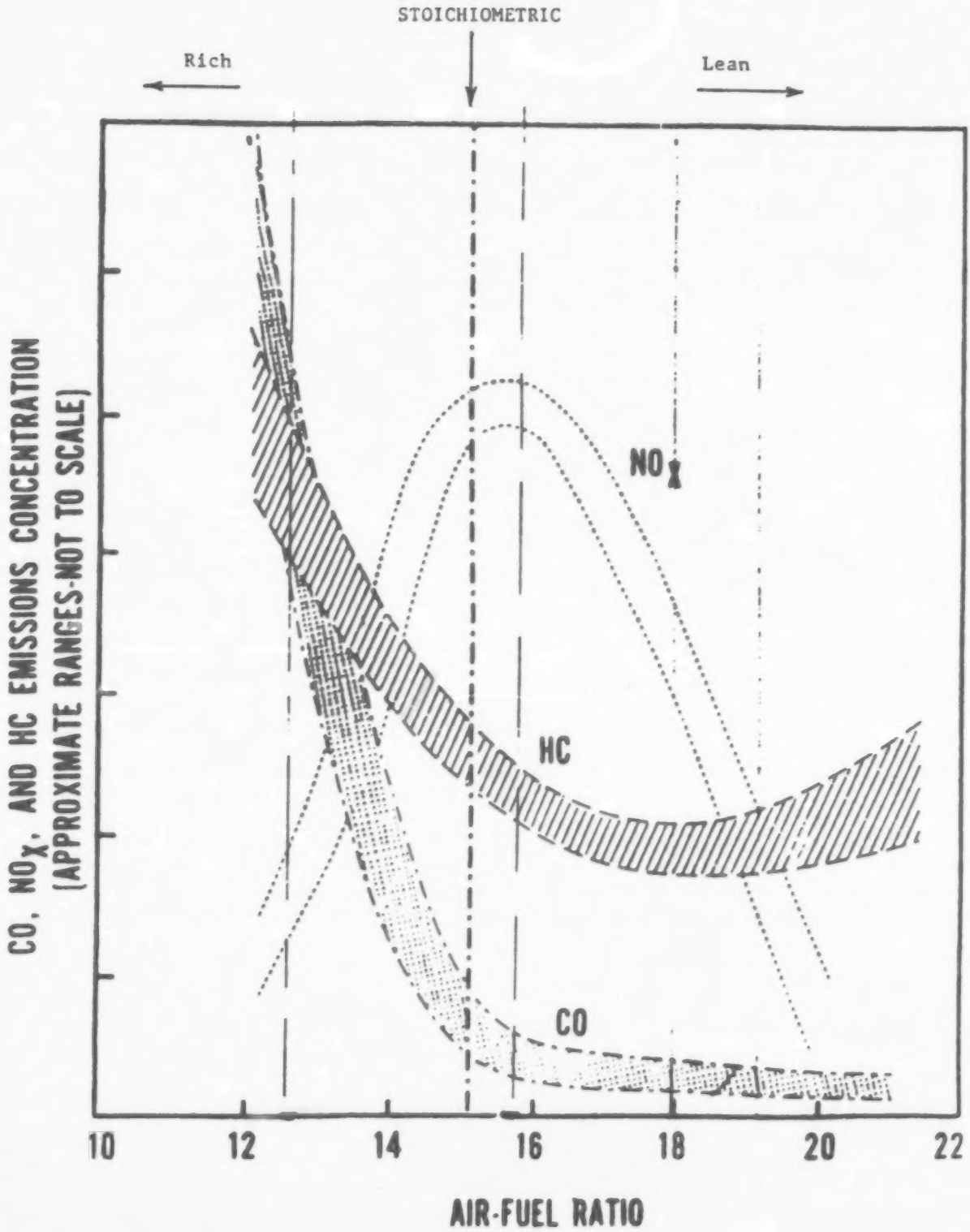

STOICHIOMETRIC
Rich
Lean
CO, NO_X, AND HC EMISSIONS CONCENTRATION
(APPROXIMATE RANGES-NOT TO SCALE)
NO_X
HC
CO
10
12
14
16
18
20
22
AIR-FUEL RATIO

FIGURE 1

PRESENTATION CANPAC '88
October 4, 1988
W.Robert Schwandt

The U. S. fuel ethanol industry is celebrating its 10th anniversary this year. Production has grown to 800MM gallons per year, giving blends penetration of 7% of total U.S. gasoline market, and over 30% in some mid-west states. Over 200 billion miles were driven on ethanol blends last year. Ethanol contributions to the U.S. economy include annual savings of over $400MM in imported gasoline, utilizes 300MM bu. of our grain surplus, saving the USDA $2.50 per bushel in support, loan and storage costs, and stimulating the economy with $3B of new investment. Environmentalists refer to it as the clean air fuel.

Early on, the infant industry received Federal grants, loans, and investment tax credits to support construction, and a partial exemption from the federal gasoline excise tax to encourage usage. 25 states also provided monetary incentives. Today, most of the state incentives have expired or been drastically reduced, and only the federal excise tax exemption is in place thru 1993. Yet the industry continues to set sales records, and sales are well established in non-incentive states, which consume about 25% of U.S. production.

Ethanol blends were introduced only after exhaustive performance tests had been run. Three of the early major ethanol producers involved world class petroleum companies: Texaco, Chevron, and Ashland. All three published results of their tests before offering the product to their customers. Meanwhile methanol blends had been generally accepted in Europe, with up to 80% market penetration in Germany, and approval by all German auto companies. Tests by Arco in the U.S, led to substantial sales of their OXINOL blend , and acceptance of a higher methanol content blend by the EPA in the duPont waiver.

visual #1: Test list

However, by 1986 negative advertising, and totally unsubstantiated reports from backyard mechanics began to appear. Alleged performance problems in Florida led to the well documented hot weather study of stalled vehicles sponsored by Amoco and the Florida Dept. of Consumer Affairs. Their data on 394 stalled vehicles identified only 4% as fuel

related, and only 2% as vapor lock. This was only 1/2 the frequency reported by Amoco in their 1969 Chicago study. The report stated "we could not determine if ethanol blends were a contributor to the fuel related stalling".

The Ethanol Corporation, the largest fuel ethanol distributor in the SE states established a series of educational seminars with gasoline retailers and automobile agencies to deal with the misinformation problem.. I participated in several of these meetings in TE and VA and later for Energy Fuels Development Corp.. in NM. It was apparent from these meetings that a solid source of reference to changes in automobiles and gasoline was needed. The RFF, the educational arm of the RFA agreed to finance the preparation of the manual distributed to you at this meeting.

Visual : Show Manual

It is now in its 2nd printing with over 1/4 million copies in use. A video is also available as a classroom supplement. All of the data and information presented in the manual is based upon publications from recog nized laboratories in scientific journals. Rather than take you thru the manual, I would like to show you a series of overheads which were developed for the seminars.

Visual: Changes in Autos
Changes in Gasoline
Is all gasoline the same?

The 1988 cold weather CRC tests have again confirmed that there are no practical differences in performance demerits between straight hydrocarbon gasolines, and splash blended ethanol products. There was some deterioration in driveablility however, with the volatility adjusted ethanol blend. This performance factor has been recognized for some time by NCWM, who only require the base gasoline blending stock to meet ASTM volatility specs. We hope and expect that EPA will also approve a 1# tolerance for RVP of ethanol blends. The ASTM is still struggling with this concept, but the CRC tests should convince them that volatility adjustment of ethanol blends is contrary to their goal of establishing performance-based specifications.

The conclusion to all this work on changes in automobiles, gasoline and the application of 10% ethanol blends can be summed up as

"If the base gasoline is O. K., the blend will also be O.K."

Test work with ethanol blends has not been limited to automotive applications. Alabama Tech. Inst. has published work on ethanol and methanol performance in piston aircraft engines which provided valuable insights on the advantages of alcohols in the combustion chamber.

Small engine testing by Sears and others has led to approval of ethanol blends. The RFF is currently financing a major study of small and 2 cycle engines showing excellent results which will be published as soon as the engine teardown examinations are completed.

Tests run by Mercury marine and others have convinced the Coast Guard that labelling of ethanol blends is unnecessary.

Visual: Mercury Marine tests

High speed power competition craft sponsored by Valvoline and driven by Dave Varney, Jim Olstad, an independent bass competitor in Idaho, and the Corn Gowers of Minnesota have demonstrated winning performances.

Visuals: Color slides

When I was in Africa last month, I observed an old 20HP Chrysler outboard operating on the local 16% ethanol blend. The owner was completely satisfied with the performance, in spite of tropical humidity conditions.

Recently the emphasis on ethanol blends has been in response to oxygenate reduction of CO emissions. The problem includes our western cities as well as the eastern urban areas.

Visual: Air Quality

Tests in Colorado have confirmed the efficacy of oxygenates for CO reduction.

Visual: Colorado Tests

These data show a lineal relationship between CO reduction and O2 content in older cars, and a less dramatic reduction in new closed loop port fuel injected engines.

Visual: CO reduction oxygen content

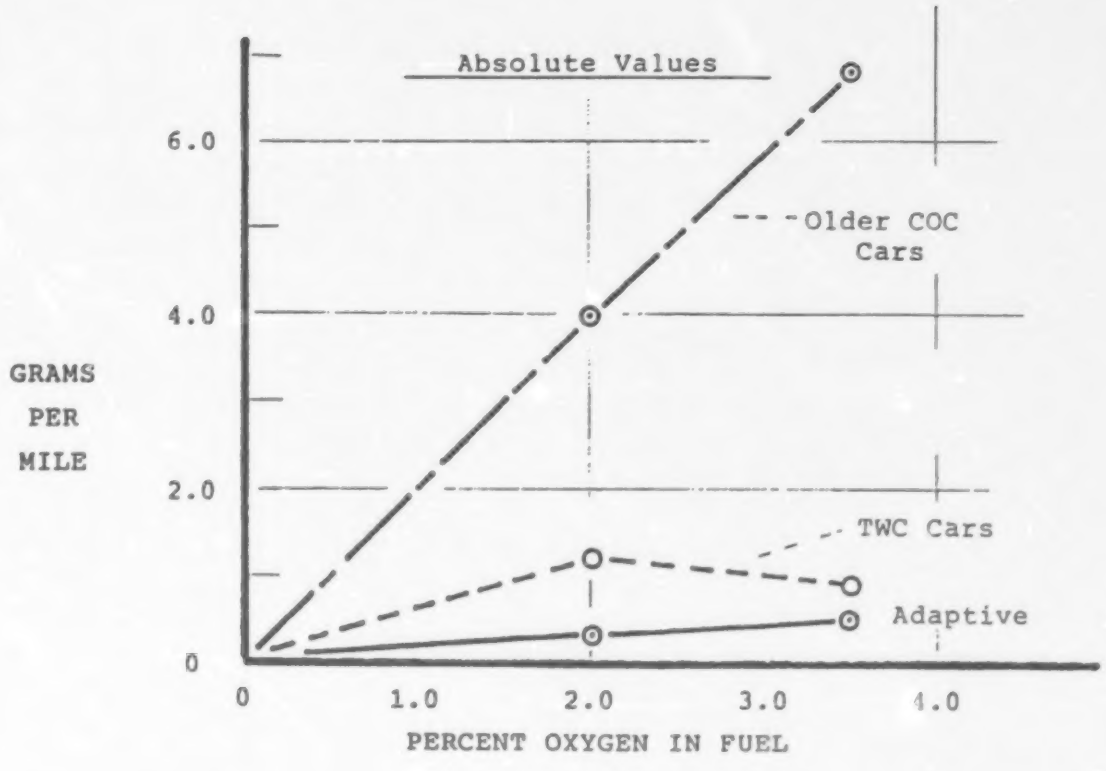
However, the fact that improvement is achieved in these sophisticated systems gives some credence to the theory that oxygenate combustions effects are more than a simple stochiometric adjustment. While many have suggested that retirement of the oldest autos would obviate oxygenated fuel advantages, the EPA in use data clearly show that as new cars become old cars, their emissions systems become less effective, providing a new generation of high pollutors.

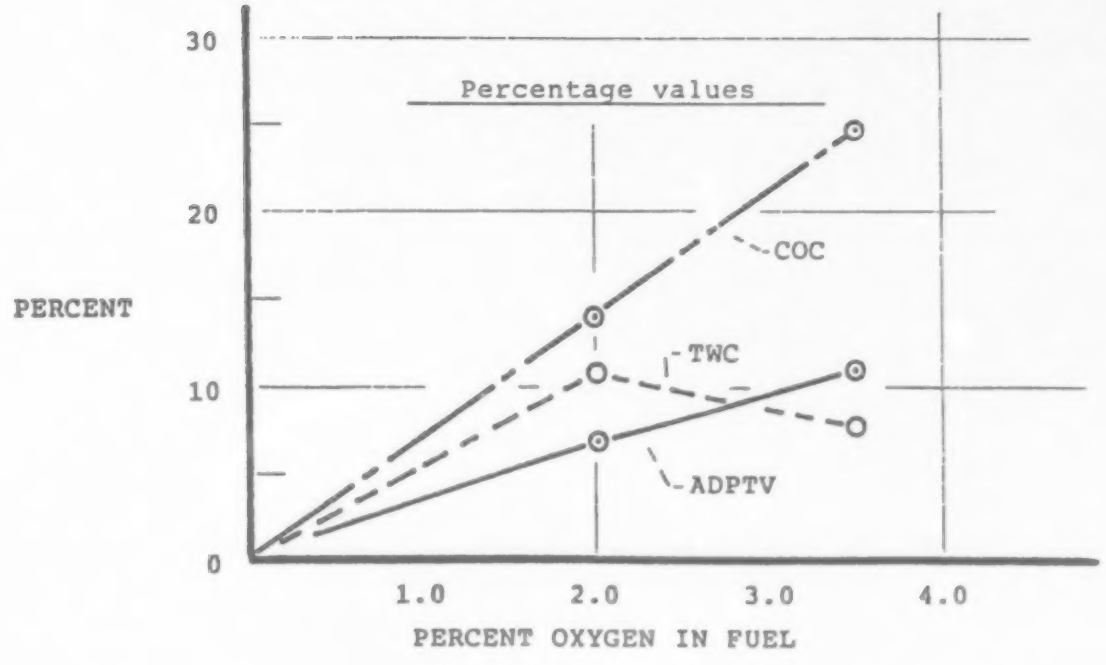
Visual: EPA In use data

I hope that this discussion has given you additional insight into the acceptance of ethanol blends in the U.S. and their current contributions to cleaning up our air.

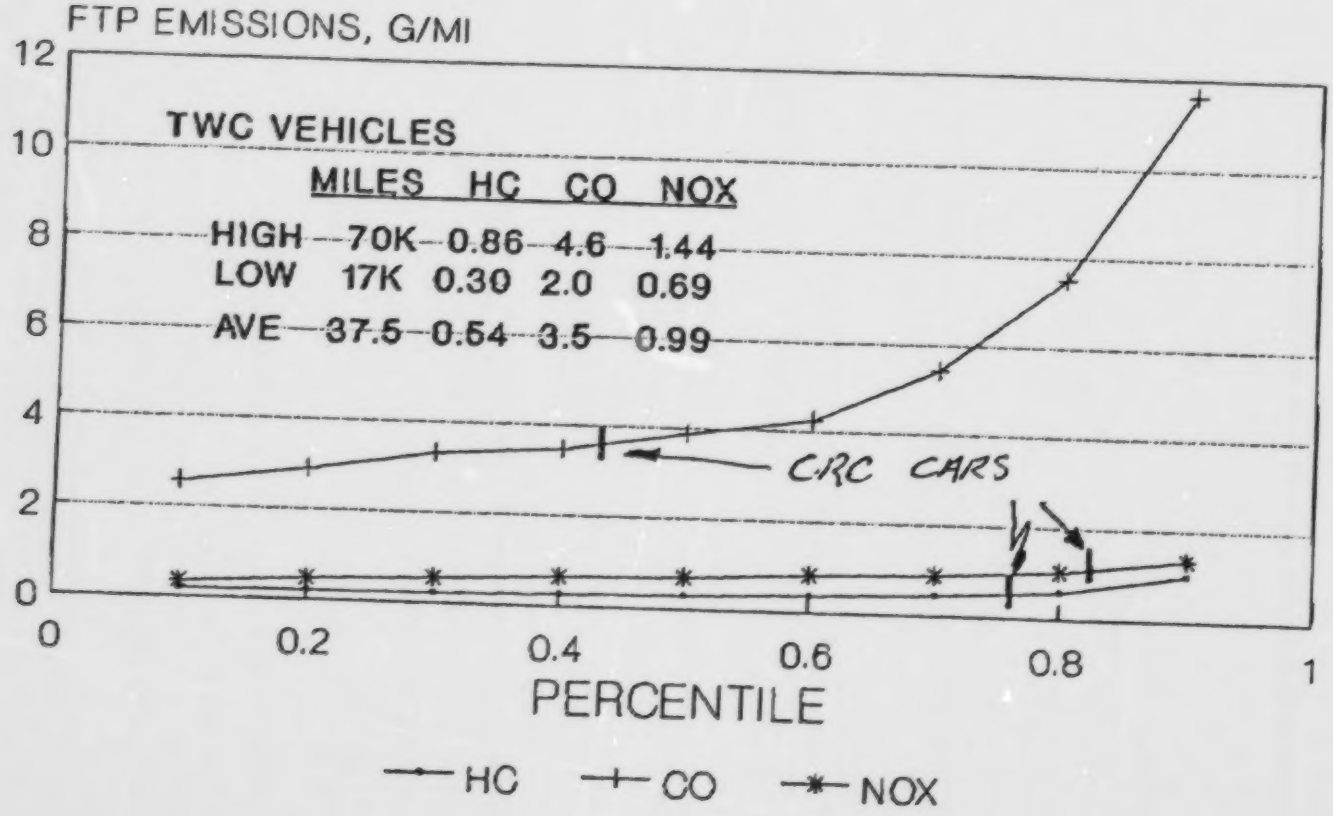
Thank you.

Figure 1. -- CO REDUCTION
Averages of 35 and 50° F Data





EPA IN-USE EMISSIONS
1983-85 MODELS WITH 40-60 K MILES



CHANGES IN GASOLINE

LEAD PHASEDOWN

Requires higher clear pool octane
Increased reformer severity
More aromatics
More high volatility butanes

HIGHER COST, HEAVIER CRUDE OILS

Increased cracker severity for bottom of the barrel yield
More olefins
More butanes and light ends

PROBLEMS

BUTANES: High volatility, vapor lock, carburetor icing
OLEFINS: Varnish, gums, valve deposits, P.F.I. fouling, reactive VOC's
AROMATICS: Driveability, softening of rubber components, very reactive VOC's, carcinogenic

AIR QUALITY PROBLEMS

68 Cities exceed Ozone limits

VOC SOURCES

Incomplete Combustion

Evaporative Emissions

59 Cities Exceed CO limits
(10 in Zone 10)

Anchorage	Boise
Fairbanks	Grant's Pass
Medford	Seattle
Spokane	Tacoma
Vancouver	Yakima

Four CO Problem Cities

	1986		1987	
	2nd High Reading	Days over 9 ppm	2nd High Reading	Days over 9 ppm
Albuquerque	12.7	15	16.3	14
Denver	25.8	33	15.6	24*
Phoenix	13.5	24	11.2	11*
Spokane	16.0	44	19.0	66

MARCH 18, 1987

FOR FURTHER INFORMATION:
H. David Billups (SPE) or
Clement J. Koehler (Mercury
Marine (414) 929-5235

spe

South Point Ethanol P.O. Box 1004 South Point, Ohio 45680 Phone: 614/377-2765

TECHNICAL DATA RELEASE

VOLUME IV

Ashland Ethanol Inc.'s joint venture, South Point Ethanol (SPE) is continuing to actively test ethanol-enhanced gasoline blends in a variety of Mercury engines to demonstrate that ethanol extended fuels are acceptable in all marine gasoline engine service. As reported in an earlier test release, the test program began on September 9, 1986 and is being carried out in conjunction with the Mercury Marine Company at its MACABO Test Center near Sarasota, Florida.

Following six-plus months of testing, Mercury and SPE are pleased to continue to report favorable results. Mercury officials report that, during this six-plus months of testing, there has yet to be any malfunction or operational driving difficulties attributed to ethanol blends.

Additionally, a second phase separation test has been completed on tanks setting a static condition for over five months. No phase separation was noted.

The following is a listing of current engines being tested:

MODEL	HOURS	MODEL	HOURS
Tohatsu-5.5	95 hours	Mercury-115 (Five)	2,215 hours
Mercury-4	120 hours	Mercury-135	137 hours
Mercury-6	235 hours	Mercury-200 (Two)	269 hours
Mercury-8	55 hours	Mercruiser-130	70 hours
Mercury-9.9 (Two)	78 hours	Cobra-140	75 hours
Mercury-25	109 hours	Mercruiser-470	30 hours
Mercury-35	88 hours	Mercruiser-205	183 hours
Mercury-45	655 hours	Mercruiser-260 (Two)	247 hours
Mercury-50	13 hours	Mercruiser-275	186 hours
Mercury-60 (Three)	757 hours	Mercruiser-350	86 hours
Mercury-80	83 hours		

Total hours: 5,786

Joint Venture Partnership:
Ashland Ethanol, Inc. Ohio Farm Bureau Synfuels Investment Company, Inc. Publicker Gasohol, Inc.

CHANGES IN AUTOMOBILES

MILEAGE STANDARDS

Downsized cars

Smaller Engines

Fuel Injection

Turbochargers

Higher Underhood temperatures

EMISSION STANDARDS

E.G.R.

Catalytic converters

Oxygen sensors

Canisters

MAJOR FLEET TESTS ON ETHANOL BLENDS

UNIVERSITY OF SANTA CLARA

PUBLIC SERVICE CO. OF NEW MEXICO, 72 VEHICLES, 800,000 MILES, 12 MONTHS TEST IN 1987-88

NEBRASKA STATE HIGHWAY PATROL, 60 MILLION MILES

IOWA STATE VEHICLES

COLORADO, 11 STATE VEHICLES IN 1987-88

ASHLAND OIL 1986 TEST 2 PONTIAC 6000 CARS, 50,000 MILES

CHEVRON 1986-7 100,000 MILE TEST ON V-8 OLDS

TEXACO 1984 TESTS ON UNDERHOOD TEMPERATURES

ALABAMA AVIATION AND TECHNICAL COLLEGE ON AIR COOLED AIRCRAFT ENGINES

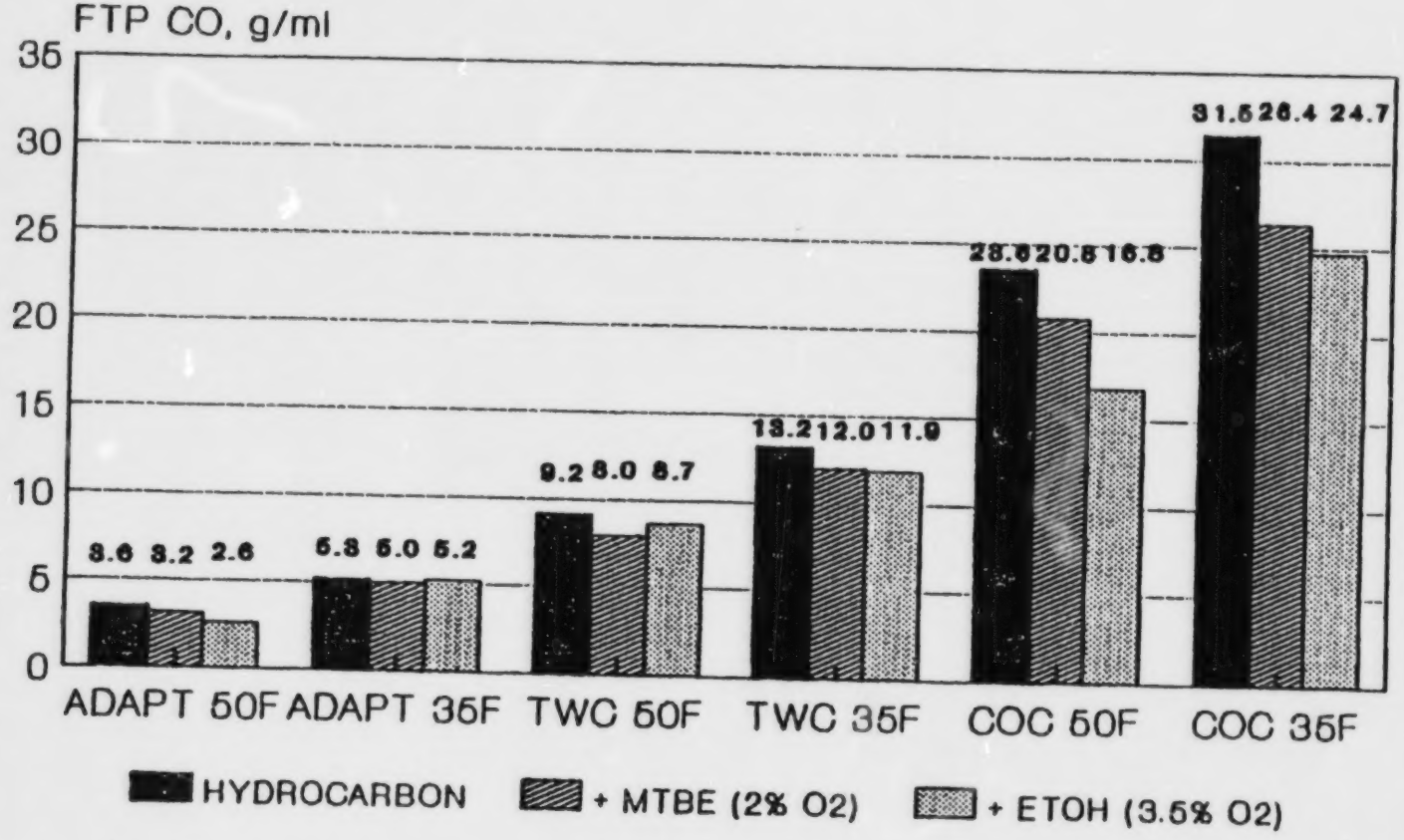
ASHLAND-MERCURY MARINE TESTS ON OUTBOARD ENGINES

SEARS,SKIDOO 1987 WARRANTY CHANGES TO APPROVE ETHANOL FOR SMALL ENGINES

FIGURE 3

Preliminary

CO LEVELS
5000 FT



6 ADAPT, 6 TWC, 4COC

Hon. Edward J. Connery, Minister of Labor, Minister of Environment, Workplace, Safety and Health, Minister responsible for the Workers Compensation Act, Minister responsible for the Civil Service Act, the Civil Service Superannuation Act, Civil Service. Special Supplementary Severance Benefit Act and the Public Servants Insurance Act, introduced Mr. Massaro. The Minister is the Member of the Legislative Assembly for Portage la Prairie.

Tony Massaro, Director of Environmental Affairs for the City and County of Denver, Colorado.

Tony attended Colorado State University, majoring in Political Science. Since 1983, Mr. Massaro has been responsible for the development and implementation of environmental policy for the city. Tony is also the Chairman of the Brown Cloud Committee of the Metro Air Quality Council, and has served on Governor Lamm's Oxygenated Fuels Task Force and Governor Romer's Diesel Task Force.

19

COLORADO OXY FUELS PROGRAM

I. Introduction
   A. Regulation (Reg. No. 13) - oxy fuels in air program area each winter season
      1. 1st year, January thru February - 1.5%
      2. 2nd year, November thru February - 2.0%
      3. 3rd year, November thru February? - 2.7%?

II. Air Quality
   1. 8-11% reduction in CO (varied based on percent of mobile source contribution)
   2. 9.5% at CAMP
   3. 11% in Colorado Springs

III. Cost
   1. $0-3.5 million TOTAL
   2. $0-1.6¢ a gallon
   3. $0-2.76 per household

VI. Public Education
   1. One million brochures
   2. Hotline - 2,600 calls (2-who do I sue, 7-who do I send the report bill to)
   3. Public Speaking - 100 engagements
   4. Efforts by other groups (Coloradoans for Clean Air, Consumers Environmental Awareness Project)

V. Enforcement
   1. Colorado Department of Health
   2. Oil and Gas Inspection Section of the Dept. of Labor
   3. 1,123 fuel samples from retail gas stations, bulk facilities, pipelines

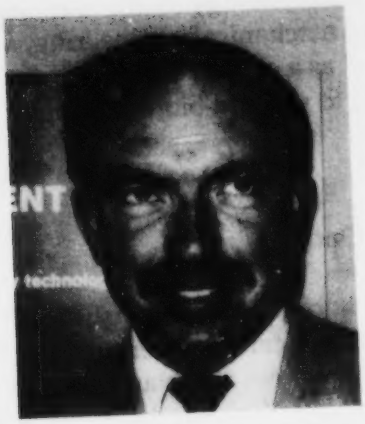
      1,049 MTBE
      74 ethanol blends
      51 deficient in oxygen content
      45 warning letters
      6 notices of violations

VI. Primary Public Concerns
   A. Fuel Economy Decrease
      1. Testing
         - no difference for 1980 and older
         - 2% decrease in computer controlled vehicles (1981 and newer)
      2. Cold Weather Testing
         - 8.6% decrease, very cold January
      3. MTBE odors
      4. 427 hotline complaints

VII. Recommendations

1. Oxygenate Marketshare
   - increase minimum oxygenate content
   - support EPA changes to allow higher oxygen content in blends
2. Require higher oxygen content fuels be available at all gasoline stations.
3. Consider shortening program to 3 months.

Doug Hayes and Hadi Husain, Co-Chairmen Session 6



Doug Hayes, Chief, Bioenergy Research and Development, Bioenergy Division, Energy, Mines and Resources Canada, Ottawa, Ontario.

Doug has a B.Sc. in microbiology and a Master's in engineering. He was a sessional lecturer and research associate at the University of Guelph in 1978 - 79 . In 1979, Doug Hayes joined Research Branch, Agriculture Canada in Ottawa, where he was a food research engineer. He left the laboratory in 1982 to serve in a number of roles in alternative transportation fuels policy and technology development for Energy, Mines and Resources Canada.

Since 1983, Doug has managed the Bioenergy Development Program supporting contract Research and Development in all facets of bioenergy conversion.

Hadi Husain, Manager, Process Engineering and Environmental Departments, Wardrop Engineering Inc. Winnipeg, Manitoba.

Dr. Husain received his Ph.D. in Chemical Engineering from the University of Birmingham, U.K. in 1972. His B.Sc and M.Sc. were obtained at the University of Panjab, Lahore, Pakistan. He has broad experience in the process design of industrial facilities encompassing power alcohol plants, including extensive assessment of the technologies for the conversion of biomass to ethanol, food processing plants, and nuclear and hazardous waste management facilities.

Hadi also specializes in energy use optimization, process energy analysis, industrial energy conservation and waste heat utilization. Recent R&D assignments have encompassed development of a novel process for biomass conversion, fermentation, evaporation, drying and membrane separation processes.

Doug Hayes and Hadi Husain are Directors' of the Biomass Energy Institute. Hadi is also involved with the Canadian Renewable Fuels Association.

Brian Foody, President, Iogen, Ottawa, Ontario.

Brian graduated from the Massachusetts Institute of Technology (MIT), Cambridge, Mass., in 1980, with a Bachelor's degree in civil and mechanical engineering, and a Master's in mechanical. After working with Techtrol as a construction engineer and consulting out of Ottawa, Brian Foody joined Iogen to work in biotechnology.

Per Assarsson, St. Lawrence Reactor, Mississauga, Ontario.

Dr. Assarsson was born in Sweden and attended Stockholm Technical Institute, from where he graduated in 1954 with B.Sc.(Honours) in Chemical Engineering. Per came to the United States in 1955, and worked as a chemical process and plant engineer. In 1961, he did postgraduate work in polymer science in New York. Dr. Assarsson spent 8 years with Union Carbide in New York in central research and product development. In 1976, Per came to St. Lawrence Reactors.

Morris Wayman, President, Morris Wayman Limited, Toronto, Ontario.

Morris Wayman has been a professor in the Department of Chemical Engineering and Applied Chemistry University of Toronto, since 1963 and in the Faculty of Forestry since 1976. His principal research areas are wood chemistry, hydrolysis of wood and other cellulosic materials to fermentable sugars, fermentation to ethanol, butanol and cell protein, lignin chemistry and utilization. Before joining the faculty at the University of Toronto, Morris directed research at Sandwell and Company Limited and earlier, was Technical Director, responsible for quality control, research and technical sales service at Columbia Cellulose Company Limited.

Hugh G.Lawford, Consultant, Bio-Hol Developments, Toronto, Ontario.

Dr. Lawford received his undergraduate and graduate degrees at the University of Toronto. His doctorate and post-doctoral training were in the areas of bioenergetics and mechanisms of biological energy conservation at the University of Dundee, Scotland. Hugh has published several scientific papers in the areas of applied biochemistry, microbial physiology and bioengineering (fermentation technology) with numerous patents relating to fuel alcohol production by bacterial fermentation, as well as processes for novel microbial exopolysaccharides.

DISTILLATION AND SEPARATION TECHNIQUES

by

Hadi Husain
Bob Parsons
David Hirschhorn

Wardrop Engineering Inc.
77 Main Street
Winnipeg, Manitoba
R3C 3H1

The subject of my discussion is distillation and separation, which is most important in the production of ethanol from biomass via fermentation. The concentration of ethanol in a fermentation broth or beer usually reaches no more than about 10 wt%. The ethanol must be separated and purified to an anhydrous product before it can be used in motor fuel. Upwards of 20% or more of the total energy, and 20% of the capital cost of producing ethanol and DDG is required for distillation and separation. You can see the importance of this operation and of making improvements.

Today, I will provide you first with some background on ethanol/water separation, the conventional process and improvements to that process, dehydration processes, and finally some advanced technologies.

Traditionally ethanol has been separated and concentrated by distillation, exploiting the greater volatility of ethanol relative to water. This effect is expressed by what engineers term "Vapour-Liquid Equilibrium", as you see represented in Figure 1. You can see from this diagram that the vapour you obtain from a lower concentration liquid mixture contains more ethanol. This enrichment of vapour concentration relative to liquid concentration is how distillation works. You will also notice on this diagram the low boiling point binary azeotrope formed at 95.6 wt% ethanol, which has important ramifications as I will discuss in a moment.

The operation of a distillation column is presented in Figure 2. Liquid enters the column and is partially vapourized. The vapour with a higher ethanol concentration as indicated by the vapour liquid equilibrium moves up to the next tray or stage, where it condenses to form the liquid for that stage. As you move in steps up a column from tray to tray, you obtain a progressively higher concentration of ethanol. This is where the azeotrope becomes an important consideration. At the azeotrope, the composition of vapour is identical to the composition of liquid. Because the vapour and liquid are of identical composition, no further enrichment can take place. Thus simple, staged atmospheric distillation cannot be used to concentrate ethanol beyond the azeotrope. You will also notice in the diagram that because the operating and equilibrium lines pinch at the azeotrope, the number of stages required as you get closer to the azeotrope increases rapidly and the column necessary becomes increasingly taller.

A schematic diagram of the conventional distillation process is presented in Figure 3. There are three columns shown: a stripping column, rectifying column and dehydration column. Beer and steam are input to the stripping column. The steam condenses, passing on energy to the ethanol in the beer. The ethanol is progressively concentrated up the column, with vapours exiting from the stripping column containing approximately 50 wt% ethanol. The liquid bottoms coming from the beerstill is the stillage, which contains residual proteins and can be used as animal feed.

Further enrichment of ethanol concentration occurs in the rectifying column, with a concentration at the top of the column near the azeotrope (95.6 wt% ethanol). A third column for dehydration is also illustrated, which I will discuss a little later on. A variety of improvements can be made to the conventional distillation process to make it more energy efficiency, including pressure distillation, vapor recompression, heat pumps and other energy recovery schemes.

Pressure distillation as illustrated in Figure 4 involves operation of the rectifying column under pressure. Steam is only added to the rectifying column. Hot vapour from this column is used to drive both the reboiler of the beerstill and the dehydration column which are both operated at atmospheric pressure.

With mechanical vapour recompression as illustrated in Figure 5, vapour from the beerstill is compressed and recirculated through the reboiler. Additional energy is thus put back into the column although this technique does involve input of electrical energy. A similar scheme illustrated in Figure 6 involves the use of a heat pump. In this overhead the overheat vapour is condensed using a heat transfer fluid, such as a fluorocarbon. The heat transfer fluid is compressed and recirculated in the reboiler to provide heat to drive the distillation. This process is not as efficient as direct-mechanical vapour recompression, but it does not involve the compression of volatile ethanol vapours.

A variety of energy recovery schemes can also be employed to increase energy efficiency by recouping heat. Through the use of heat exchangers, beer can be preheated prior to entering the column by using this stream for instance to

condense overhead vapours. Similarly, boiler water can also be preheated. Distillation systems have also been integrated with stillage evaporation.

As I noted earlier, traditional staged distillation can only concentrate ethanol to the azeotrope, and alternative techniques must be employed to dehydrate this resulting mixture. The conventional method employed for this purpose is so called "Azeotropic Distillation". This process involves the addition of a third component or entrainer such as benzene, pentane or cyclohexane to disrupt the binary equilibrium. In the case of benzene, for instance, a three component azeotrope is formed which scavenges the residual water, allowing remaining ethanol to be recovered in a pure form. In the conventional process, illustrated in Figure 3, a single dehydration column is employed. Depending on the entrainer employed upwards of three columns can be required to dehydrate the ethanol stream and recover the entrainer. Azeotropic distillation is unfortunately very energy intensive and expensive so there is thus a strong motivation to find less costly and more efficient methods.

One such technique which has been commercialized and presently is in fairly common use is the use of molecular sieves. Molecular sieves are made of zeolite aluminosilicate materials. The zeolites employed have very regular sized aperture openings on a molecular scale, and possess a very strong adsorptive selectivity and capacity for water. The molecular sieves are employed in beds in a cyclic manner. In Figure 7 two beds are shown, one dehydrating the ethanol product while the second is regenerated. Vapour enters the bed, and the water is adsorbed by the zeolite. This procedure continues until the bed is saturated with water. The bed is then switched to regeneration. Superheated ethanol containing vapour is directed into the bed which removes the adsorbed water. The vapour mixture from the bed is returned back to the stripping column at an appropriate tray.

A variety of advanced concepts for separation of ethanol and water are presently under development. These include vacuum distillation, vapour stripping, extraction, extractive fermentation, and the use of semi-permeable membranes.

Vacuum distillation is based on the fact that water content in the azeotrope drops with pressure. In fact it would be possible to obtain pure ethanol if the pressure could be dropped to zero. This scheme offers potential for energy use reduction by incorporating vapor recompression. The prohibitive capital cost and complexity of the system are key problems.

One interesting concept which has been worked on here in Canada is vapour stripping as illustrated in Figure 8. Carbon dioxide gas, generated by fermentation, is recirculated through the fermentor to strip ethanol from the beer. The saturated gas is cooled using cold water and the condensate recovered. Unfortunately, the ethanol concentration in recovered condensate is only about 20% and must still be further purified. The process does, however, offer the potential to maintain ethanol production rates at higher levels by continually removing toxic ethanol from the fermentor.

Solvent extraction of ethanol from water as illustrated in Figure 9 has been receiving increasing attention. Such solvents as dodecanol, ethylhexanol and fluorocarbons have been investigated. Extraction processes, however, are presently limited by the relatively poor selectivity and capacity of the solvents involved. If better solvents can be found, this process offers good potential. A similar process, which you heard Dr. Daugulis from Queen's University describe yesterday, is extractive fermentation as illustrated in Figure 10. In this case, a biocompatible solvent removes ethanol directly from the fermentor, reducing toxic inhibition and maintaining ethanol production rates at higher levels. In the case of both extraction and extractive fermentation, if the proper solvent can be selected, it may be possible to recover very pure ethanol from the solvent.

The last area I will discuss today is the use of semi-permeable membranes for ethanol/water separation. A variety of configurations have been proposed using membrane, some of which I will show you here today.

Illustrated in Figure 11 is the use of liquid phase reverse osmosis to remove the smaller water molecule from the larger ethanol molecule. The concentration of ethanol which can be obtained is presently limited to the range of 12 to 15 wt% because of the extremely high osmotic pressures involved.

Another membrane process illustrated in Figure 12 is pervaporation or "transmembrane permeation evaporation" where the feed is liquid, but the permeate is vapour. Membranes with very high pervaporative selectivity for water have been developed, and pilot scale pervaporation dehydration plants have been constructed. Some very interesting ethanol selective pervaporation membranes have also recently been investigated in Europe, which incorporate organoselective zeolite materials. In a membrane dehydration system as illustrated, the energy input required is reduced to the latent (vaporization) energy of the water removed.

An interesting extension of membrane separation as presented in Figures 13 and 14 is to look at vapour phase separation of ethanol or water. In this case, the energy required is that to maintain the vapour in that phase.

To give you some idea of the numbers involved, I have presented some typical energies required in separation in Table 1. To concentrate ethanol from 10 wt% to 95 wt% by conventional distillation requires about 5,100 MJ/L. Azeotropic distillation to purify from 95 wt% to 100 wt% requires an additional 2,600 MJ/L for a total of 7,700 MJ/L.

By use of presently available techniques of vapour recompression in distillation and molecular sieve adsorption for dehydration the required energy can be reduced impressively to about 2,200 MJ/L. It is likely that this number may be reduced even further through the use of developing advanced technologies.

In conclusion, distillation remains the key separation technology for ethanol recovery from beer, however, impressive improvements have been made to the conventional process. Several developing advanced technologies, especially extractive fermentation offer unique approaches. Significant developments have occurred, and are likely to continue in dehydration.

FIGURE 1

VAPOUR-LIQUID EQUILIBRIUM
TYPICAL CURVE NEAR ATMOSPHERIC PRESSURE
- NOT TO SCALE

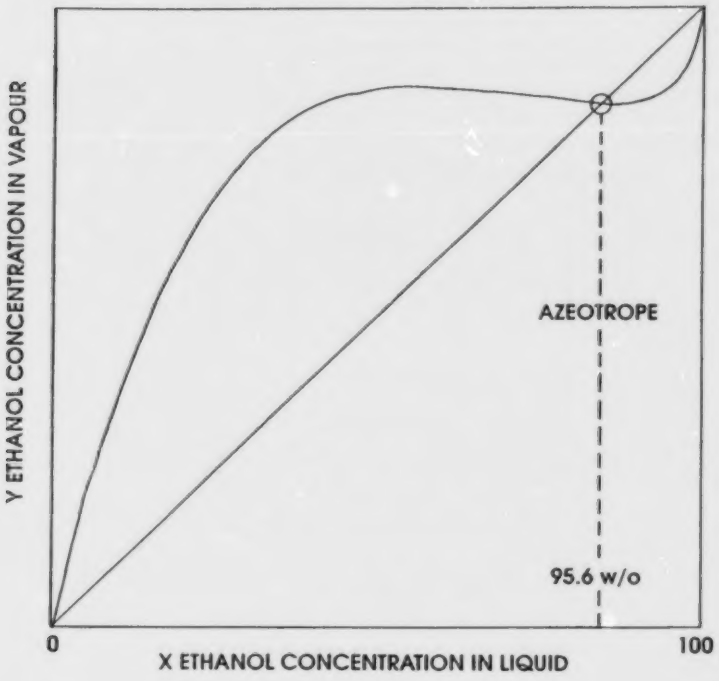


FIGURE 2

CONTINUOUS STAGED RECTIFICATION

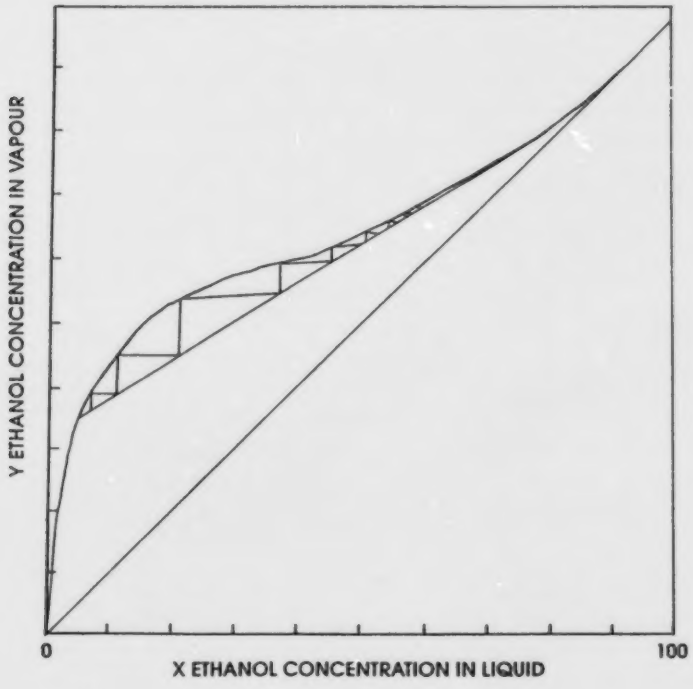


FIGURE 3

CONVENTIONAL DISTILLATION

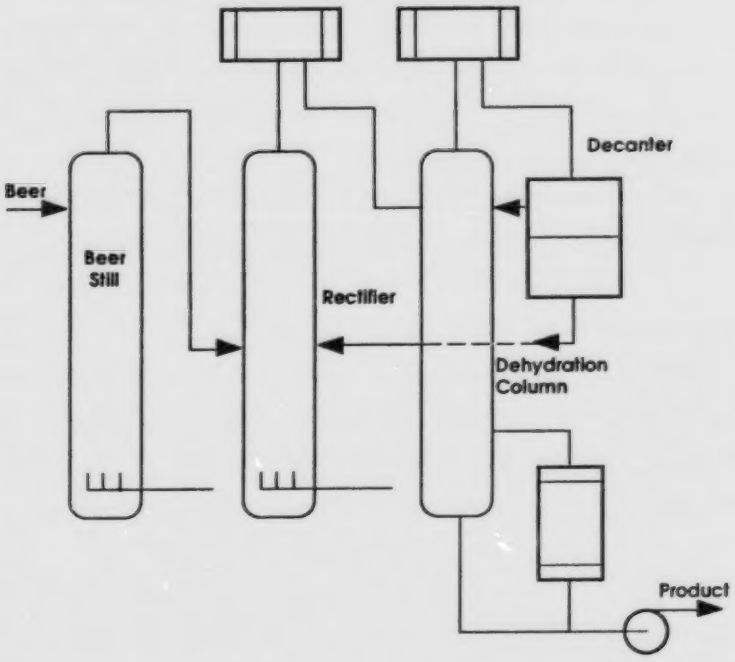


FIGURE 4

PRESSURE DISTILLATION

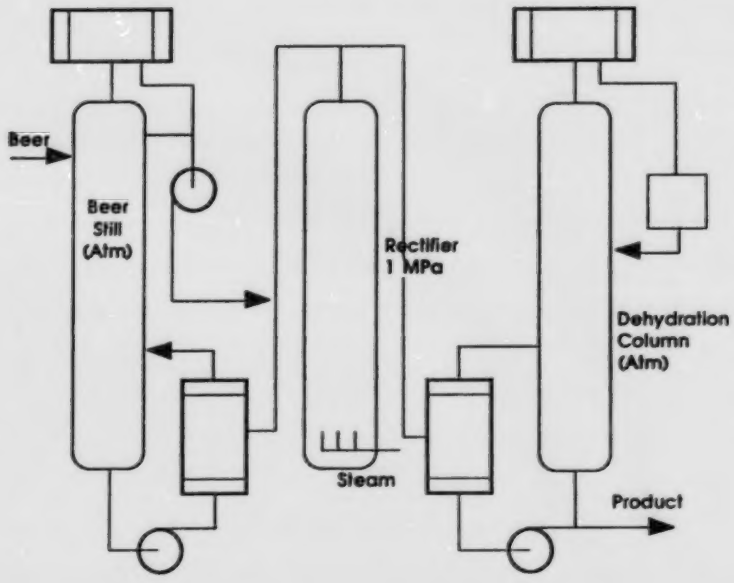


FIGURE 5

MECHANICAL VAPOUR RECOMPRESSION DISTILLATION

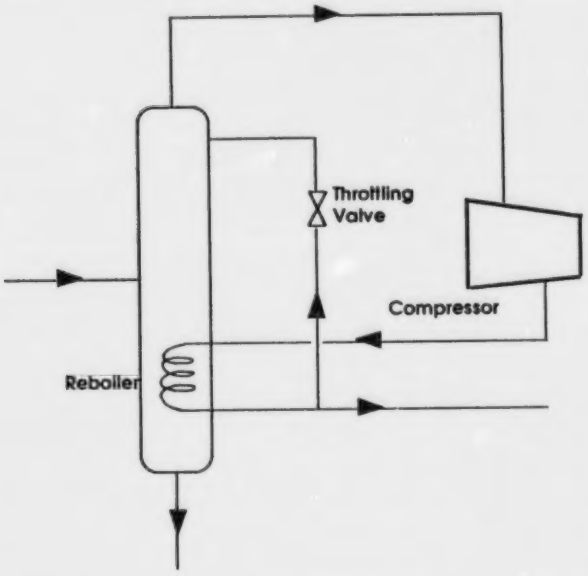


FIGURE 6

HEAT PUMP POWERED DISTILLATION

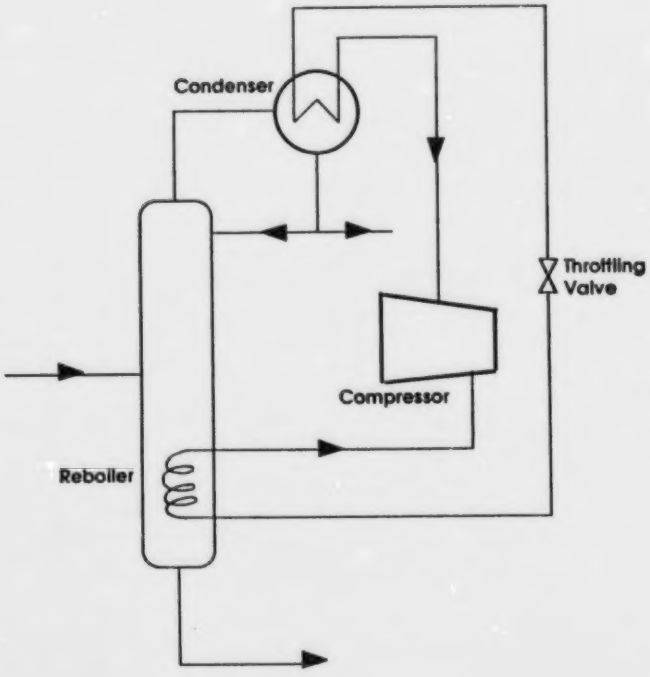


FIGURE 7

MOLECULAR SIEVE DEHYDRATION

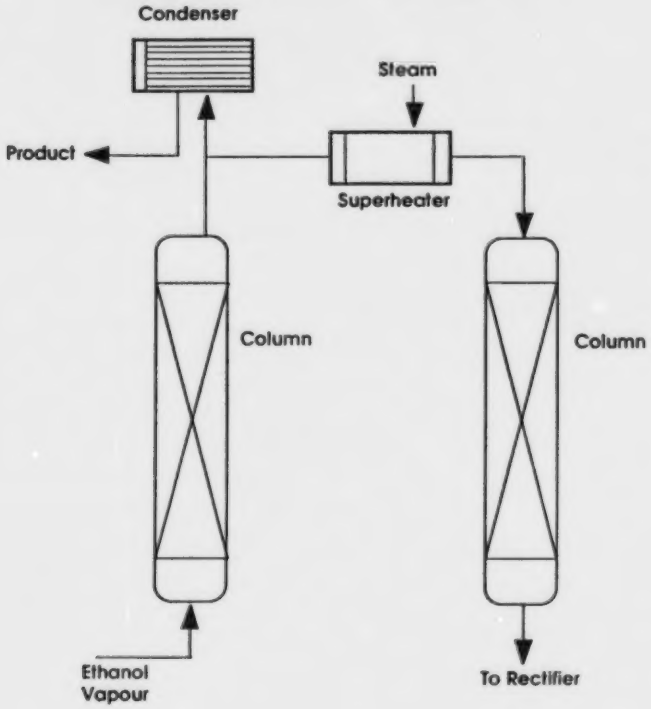


FIGURE 8

GAS STRIPPING

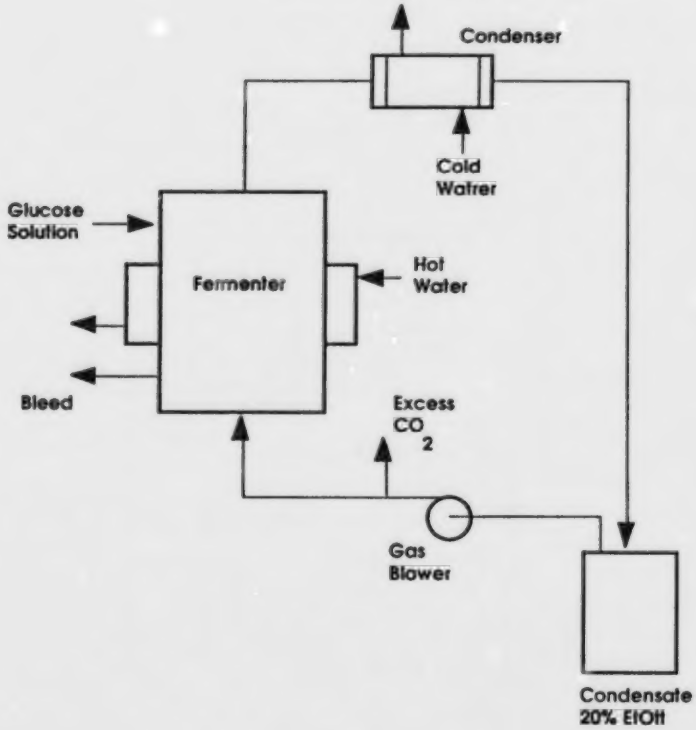


FIGURE 9

EXTRACTION

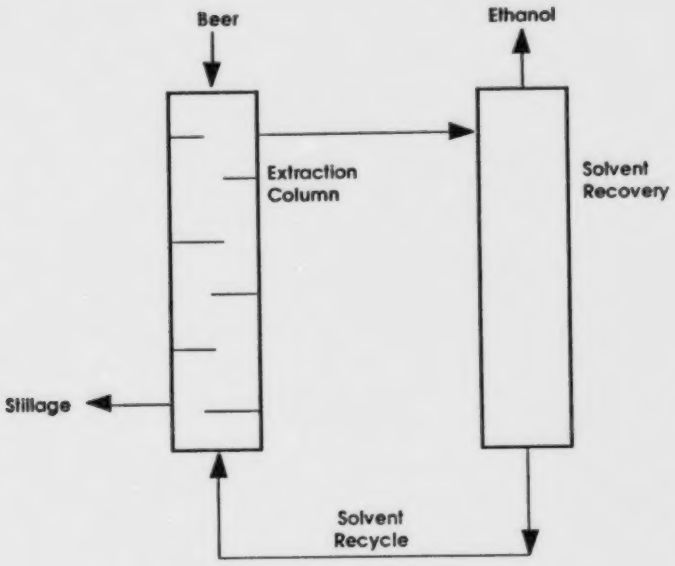


FIGURE 10

EXTRACTIVE FERMENTATION

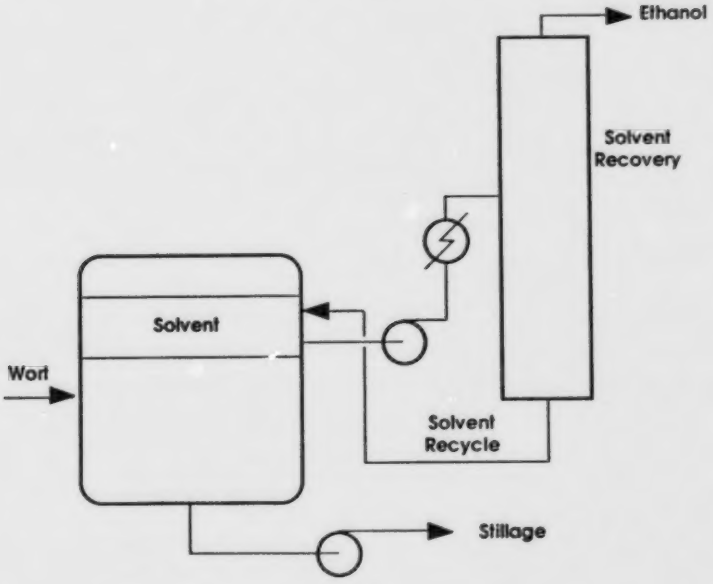


FIGURE 11

MEMBRANES: REVERSE OSMOSIS FOR PRE-CONCENTRATION

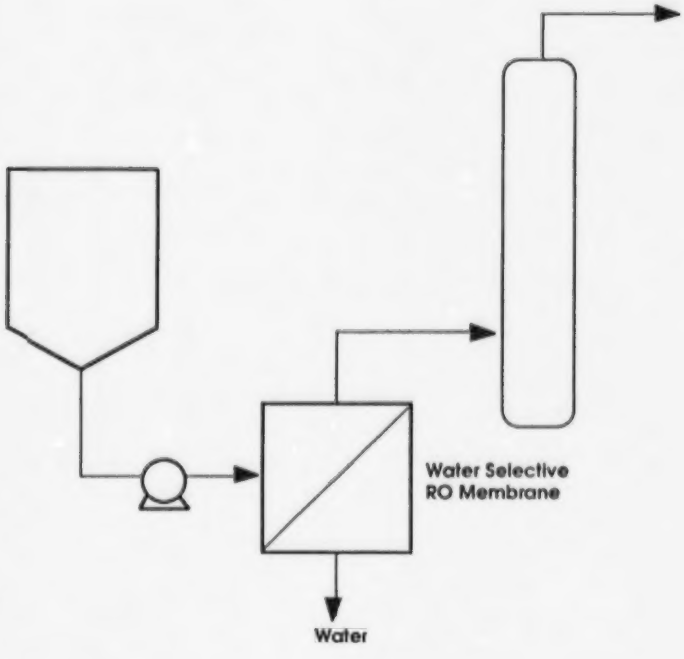


FIGURE 12

MEMBRANES; PERVAPORATION FOR DEHYDRATION

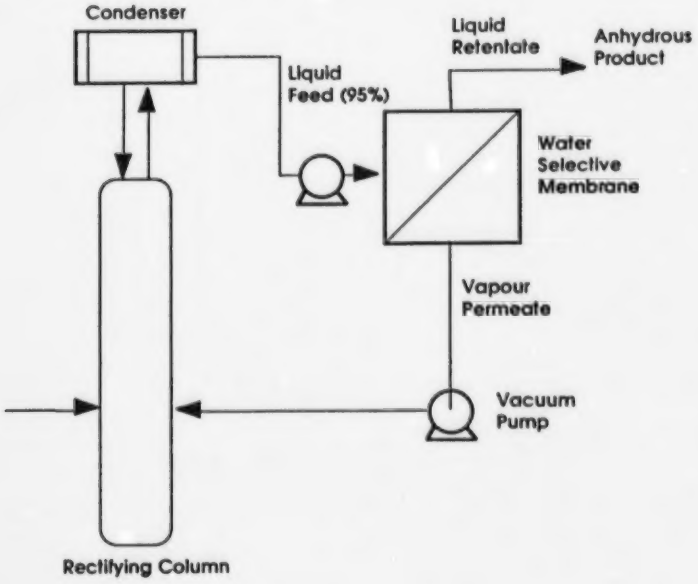
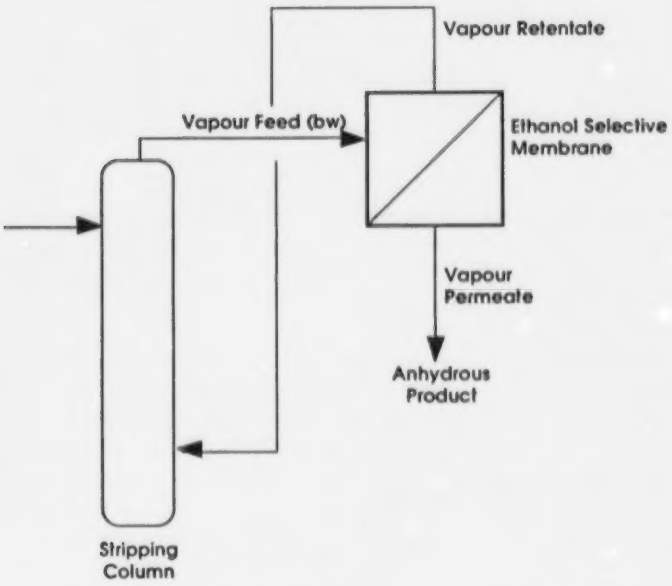


FIGURE 13

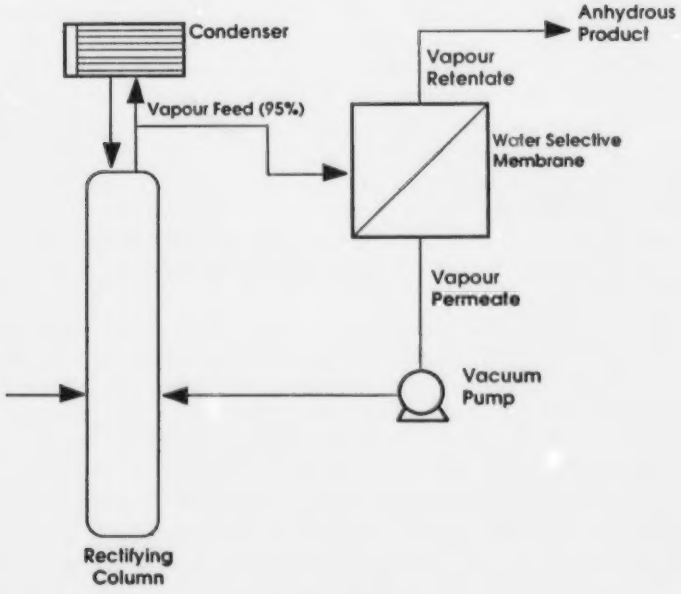
MEMBRANES: VAPOUR PHASE ETHANOL PURIFICATION



Theoretical Only

FIGURE 14

MEMBRANES: VAPOUR PHASE DEHYDRATION



PROPOSED ONLY

TABLE 1

ENERGY USE

	MJ/L
Conventional	5100
Azeotropic Distillation	2600
Vapour Recompression Adsorption	2200

ENZYMATIC HYDROLYSIS

by

MR. BRIAN FOODY
PRESIDENT, IOGEN
OTTAWA, ONTARIO

Thanks very much Doug. I certainly appreciate the opportunity to speak here. What I'd like to talk about is up on that slide. I'm going to be talking about ethanol production from cellulose and I'd like to cover a couple of issues in this area. First, what is ethanol worth in current gasoline markets; then what will it actually cost. How does this compare with non-conventional frontier oils which, at least our Canadian government, has been very generous in financing of late. Then why would you look at ethanol from cellulose, because there's already existing well developed technology for making ethanol from other routes. And I'd like to take a look at what the important factors are; where we stand today and finally, what needs to be done.

Well, first of all, let me talk about what ethanol is worth in current gasoline markets. I should probably start this with an apology, because there's no doubt there are a lot of people in this room who know far more about it than I do. I'm just summarizing this pretty much as a layman, but I hope that it's mostly on target and generally fits in with what you've heard from other people. First of all, ethanol can be used for a number of different properties. One would be for strict gasoline substitution where, if it's used in a E10 or ethanol/methanol blend it just substitutes one for one for gasoline. If it's used in a neat fuel application, because it has a lower energy content than gasoline, you need a litre of ethanol to replace only something like 0.8 litre of gasoline. It also has co-solvent properties where it can be used to bring methanol into a gasoline mixture. In that sense it can gather value, if methanol happens to be worth less than the other ingredients in gasoline. Depending on who you are and whether you need octane, it can contribute to octane enhancement. We heard that Sunoco's problem is not so much octane enhancement as giving octane away for free. And then, finally, it has environmental implications. It obviously contributes to octane in unleaded gasoline, reduces carbon monoxide emissions but it has a flip side in terms of increasing vapour pressures and aldehydes as we heard earlier today.

Now with those pluses and minuses, and addressing this question of what's it worth in gasoline markets today, the answer is you can't really say. It depends upon who the purchaser is; what kind of application or set of those properties the purchaser is going to use; and if he's blending with methanol, what methanol is worth. So what I've done here in this chart is just summarize some of the different applications. Obviously, one of the great problems of saying what a material is worth in gasoline markets today is that that may be different than the day before yesterday, and I just have a couple of the assumptions written up there. The lowest value you'd really find for ethanol would be for an integrated oil company who has an existing refinery operating. Our ballpark estimate is that he'd

see a short-run variable cost - based on short-run variable cost, you'd only be willing to pay about 17¢ a litre for ethanol. Now that's not a whole lot of money by comparison to what ethanol people would like to sell the material for, but I think it's a reasonable estimate of what the actual straight economic trade offs are for the oil companies. If you're a gasoline marketer, however, and you don't have to worry about backing out material going to refiners - you don't have to cover the fixed cost of a refinery - you could pay somewhat more for it. And then as you walk down the line, if you can use the octane and get full marketplace benefits for the octane, it's worth something to you. If you can bring methanol in as a co-solvent and get values for both the substitution and the octane enhancement, it's worth something to you. And by the time you get to the very bottom of the line you have a possibility of values ranging from 17¢ a litre all the way up to a high of 60¢ a litre for a person in the optimum situation in the marketplace. I think it's probably fair to say though that as our gasoline market, in large measure, is made up of integrated oil companies, most of the customers out there are thinking in terms of 17-20¢ a litre ballpark in terms of what they want to pay for this material, solely on a economic basis.

So, just to try and summarize that in terms of what the oil price is, and I think that's an important perspective, what I've plotted up here along the X-axis is the price of oil, and along the Y-axis is the ethanol value, under several different scenarios. The lowest scenario is for neat ethanol. That line approximately follows what an integrated oil company might pay for ethanol as a function of the oil price. And then the highest line all the way up at the top is what a gasoline marketer, whose getting low price for methanol and full value for its octane, might be - where his break even might be. Along the lower axis, you'll see, I've also noted where some of the energy products that have got support from the Canadian federal government stand. The Hibernia has just recently got the go ahead, or at least go ahead for engineering. This is just something of an indication so that when you try to put in perspective what the Canadian government's trade offs have been in terms of pricing oil, pricing these large energy projects, where it might compare with ethanol. These numbers here are not our own, but rather taken from a public Husky Oil report, and cover not the unloaded, the no-load costs that people normally like to report but rather the full cost, including taxes and returns, and all of that. So you see, we're getting ourselves in for some pretty expensive oil with projects like Hibernia.

So now, let me address the, I think, very important question of why ethanol from cellulose. I think, if I was going to say why ethanol at all, I think the bottom line answer has to be either it's going to come in on cost or it's going to come in because it's some kind of externality like environmental performance, or whatever. From here on, what I'd like to address is not specifically why ethanol might enter the market, but why you might look at cellulose as a possible source for ethanol.

What I've outlined here is just a very simple block flow diagram comparing the overall processes for making ethanol from corn and from wood. Let me just summarize the reasons you might look for cellulose as a source of ethanol rather than corn. First of all, cellulose, by its nature, is going to be a lower cost raw material. That's essentially driven by the

fact that it grows much faster, and it can be much less expensively harvested. Now, another reason why you might look at it is because there's so much up sided improving the overall process from where we stand right today. Ethanol processing from corn from conventional routes essentially reached its limit in terms of technology improvement. Even bar Hadi's description, I think we can all agree that there's not a whole lot of money that can be saved in terms of process improvements and overall ethanol production. And then finally, the potential for by-product improvement. So if you look now at the overall block flow diagram, you see, in both processes you begin with corn or wood; you process the material; typically add enzymes which break the cellulose or starch down into glucose; and then from that, you distill the material. The big costs around wood conversion, while it's a much cheaper raw material, are in those biotechnology aspects that - making an enzyme that will break the material down into glucose. The costs in fermentation and distillation are essentially comparable. And then when you get down to the bottom, there's a huge difference in by-products, that as you'll see later really drives the economics.

Just a brief illustration to try and show you why there's such a similarity. Starch and cellulose are both long-chain polymers of glucose - one linked with alpha linkages, the other with beta linkages. The alpha linkage is very easily broken down in nature, amylases are very successful enzymes in doing that - that's why its so inexpensive to break starch down into glucose. The bonds in cellulose, on the other hand, beta 1-4 linkages, are much more difficult to break down - the enzymology and technology for making enzymes to break them down is only just coming available right now.

Just to call up an old slide that I've shown for a long time. This gives you an idea of what's been happening in the field of making enzymes for breaking cellulose down into sugar. Along the X-axis you have the year in which a certain result was achieved and that result being in the productivity of making enzymes - what I've shown along here are really the public domain, state of the art results. You'll see that in the mid-70's people were producing enzymes with productivities in the five to ten unit per litre hour range, and the best reported results now are nearly a hundredfold higher than that. The technology is actually been improving at a pace of nearly doubling every two years. And that's very important, because if you look at the overall differences between starch conversion and cellulose conversion, it all comes down to the biotechnology in the enzymes. And with continued improvement, I think, if the technology can be improved to the point where cellulase enzymes worked as well as amylase enzymes, there would be no doubt whatsoever that cellulose would be a very low cost for producing ethanol. Crucial question is, can those technical improvements be made.

Now, let me address briefly what it might cost to produce ethanol from cellulose and from other materials. What I have here is a bar chart that compares the estimates from another series of publicly available reports. Along the Y-axis there you have the ethanol costs in cents per litre. You can see that there's some pretty broad spectrum ranges with respect to the ethanol from grain; that depends on the plant size and upon by-product credits from that. Ethanol from cellulose in both the higher version, what technology was available in 1986, and the lower version, for

which I'm saying, what happens if we get a certain level of improvement, I'm calling it future technology. There's still quite a bit of uncertainty that's in part driven by by-product credits and in part driven just by the fact that one has to be speculative if you're looking at the cost of large scale ethanol production. But you can see that it's plausible at least that ethanol from cellulose can become quite inexpensive. That lower cost than grain is driven largely by the lower raw material costs. Next slide.

Now, an interesting question comes up. How do those numbers compare with non-conventional or frontier oil? Our government is committing billions of dollars into those types of materials. So what I've done here is just superimpose two charts from the previous - that I've shown previously. Along the Y-axis you've got the cost of ethanol in cents per litre; along the X-axis you have the oil price. You can see that ethanol from grain - and what I'm going to do is follow along the neat ethanol line because that's the line at which our large oil companies might actually decide they'd like to buy ethanol, or it's the price where ethanol could actually compete in the market used in a neat form. You can see ethanol from grain is roughly competitive at least with what some of Husky's estimates have been for oil sands. You can also see that ethanol from cellulose, presuming technical advances are made, is coming into a range where it's certainly competitive with the large scale oil products which our government has put so much faith in, and perhaps it's even coming down into the range where it can compete today. Now, that doesn't mean that there's going to be a plant standing up tomorrow doing this, but rather that this is a very plausible type of technology to develop, and a plausible thing to happen. Next slide.

So now what I'd like to do is just address what factors are important in the overall economics - to give you a sense for where the sensitivity to all of this is. Next slide.

Four important areas: Number one is the plant size, depending on whether you have a big plant or a little plant makes a huge difference in terms of your overall economics. That holds true in similar industries like corn milling, or in the pulp paper business, or in the refinery business. A ten million litre a year refinery would not be something oil companies would look forward to building. Next item is by-products sales. By-products can be crucially important to the overall economics of cellulose to ethanol as they are in starch to ethanol conversion. The third one which I touched on earlier is the technology. Cellulose to ethanol conversion is still very technology intensive, there's still substantial room for technical improvement, and if those improvements can be made, the cost will be coming down significantly. Finally, once the technology improvements are made, we really start driving ourselves to the point where raw material costs are important. Now, obviously if one was to say, how much would corn or wheat cost if you were using technology for producing corn and wheat to predate the grain revolution - you're using wheat varieties from 1890, then the material would be quite a bit more expensive than it is today. Technical advances in plant genetics have not yet been applied to tree growing. Next slide.

So, where do we stand today. Next slide.

Just to give you a sense where I'm coming from, what I'm going to do is look at each of those sensitivities from two - I'm going to give you a comparison of two separate estimates. We've taken estimates prepared by a sister company of ours, Techtrol Limited, and also by Arthur D. Little, a well respected consultant based in Cambridge, Massachusetts. In both cases we've used conventional chemical engineering factor methods to take a look at the sensitivity to different effects, such as plant size. Next slide.

So, the first one to look at here is the effect of plant size. Along the X-axis you see plant size; the Y-axis you see the price of ethanol in cents per litre. Two estimates, Techtrol and the ADL estimate are both shown. Terms of where we stand today, the largest operating plant in the world is run by my company, and it's one tonne per day. You can see that the ethanol produced in that facility is extremely expensive, far too expensive to be economical, but as plant size increases to processing plants in the order of one to two thousand tonnes a day, one is starting to get into the maximum, optimum size. Now this is no coincidence that you're looking at two thousand tonnes a day, because that's pretty much the ballpark of where the most cost effective pulp and paper and corn wet milling facilities are. Obviously the corn wet miller in the room could tell me a little bit more about it, but I think that the most corn wet milling plants get up to about four or five thousand tonnes a day, and pulp and paper mills reach as high as four thousand tonnes of wood received, and a typical size might be in the one to two thousand tonne a day received level. Next slide.

Now, moving from that base case where we were in the 30-40¢ a litre range, what I'm plotting here is the effect of the major by-product, lignin, on the cost of ethanol. You can see that lignin's selling is critically important to the overall costs of making ethanol. I've got several instances shown here. The upper line is the estimate made by Techtrol; the lower line the estimate by Arthur D. Little. The range, if you can sell lignin for something over 40¢ a kilogram, which would go into application such as PF resins or lignin plastics, you can be making ethanol pretty darn cheap. In fact, you can be making it for almost nothing, you're making so much money on the lignin. Now there's been a lot of studies and a lot of people who have looked at materials that can be made from lignin. Particularly now there's quite a bit of interest in what you can make from novel lignins such as might be produced in this type of a process. They're different in some degree from what pulp and paper lignins are, and I think there have been estimates that show in those scale of markets that billions of litres types of quantities of ethanol can be manufactured. As you move down into the lower end and say, what happens if we're building this big plant and you can't get these high volume applications. What about lower end types of things. By lower end, I might look at say, asphalt replacement or uses of carbon black replacement or liquefaction. When you're pushing down into 10-20¢ a kilogram range. And with technology available in 1986, in that ballpark you're looking in the 30-50¢ a litre range - something not a whole lot different than what grain processing might be. Next slide.

Now, taking the big hit, we say what happens if you look at the impact of technology. What happens with technical advances. You see there nearly 30¢ a litre that you've shaved off solely by reductions in the cost

of the enzymes. Here this target technology that I've indicated is a four-fold improvement in overall enzyme technology. And you can see that that makes a big difference to the point where ethanol, when lignin is produced or sent into asphalt type applications, can actually be meeting the criteria of oil companies today to buy the material in the 20¢ a litre range and can certainly be competitive with large scale oil projects that have been financed by our government. I might say parenthetically about the technology, that over the last five years the level of enzyme technology has been doubling roughly every two years, so we're not talking about a static situation here. Next slide please.

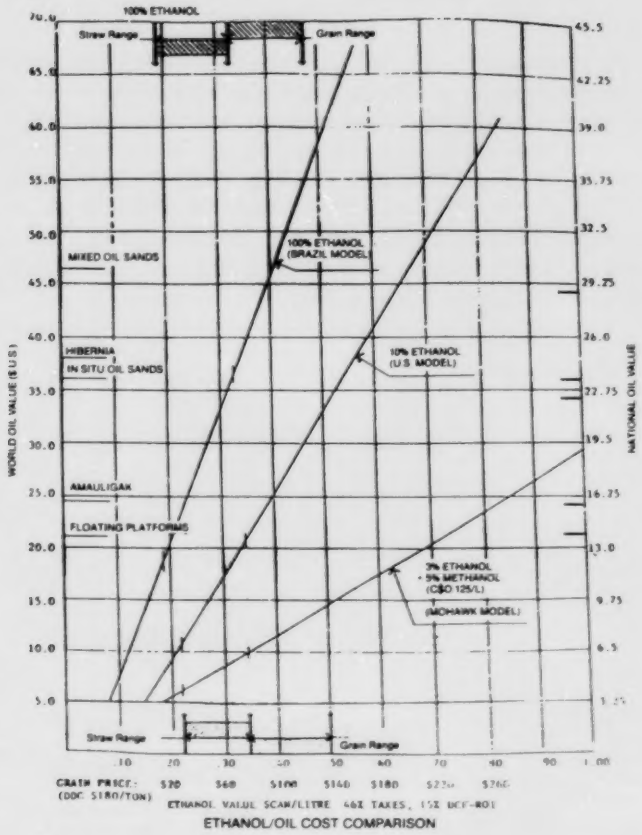
Finally, let me just illustrate here what the impact of lower wood prices would be. The base case that we were working on was $40 a tonne, which is the delivered price that we got some actual quotations on. I'll show a little bit later a rationale for looking at a plausible price in the $20 per tonne range - not a certain one, but a plausible one. And you can see that this - that now wood prices are starting to play a big role in the costs and overall, there's perhaps 5-10¢ a litre play in that area. Next slide.

Just to illustrate what's been happening in overall technology of wood production, we made a very first cut cost estimate. Along the Y-axis is the cost of wood in dollars per tonne and along the X-axis is the growing rate of trees. We took an estimate done by the Canadian government and said what happens if you just say, look at improvements in the overall technology - the trees grow faster - how would that affect the cost. Using what was the state of the art in about 1980, the estimate was that you should be looking about $40 per tonne wood. But with improvements in growth rates that have been published, the costs are coming down, pushing towards the $20 per tonne range, and our guess would be that that's about where the level off point would be. This is really very much a first cut here, but it still is an indication that there's room for improvement in all of these different areas related to cellulose/ethanol conversion because the technology is still very new and certainly not even reached a commercial application. Next slide.

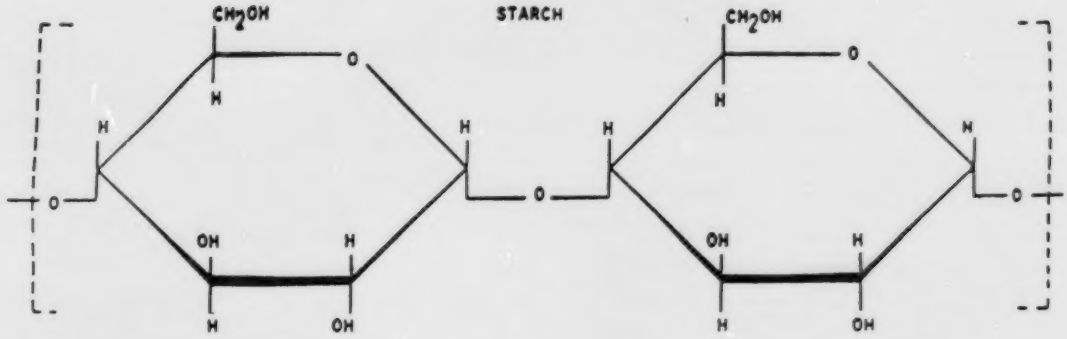
So let me just summarize this talk and try to give you a few important take home messages. First of all, in our view ethanol can become a viable long-run substitute for gasoline. The basic economics are there given the technology improves for it to compete with perhaps gasoline even today and certainly with the perception of what gasoline prices might be in ten years, or thereabouts, which would almost be the time frame for being able to have large scale facilities in place. The key issues that have to be looked at: Number one, our technology improvements, first in the process and then in reducing the cost of the raw material. The next, which I didn't address in great detail in the talk, was the scale-up strategy; first technical because one can't just skip from a pilot plant processing one tonne a day up to thousands of tonnes a day facilities. For technical reasons there are risks in scaling up any of these types of new processes; the second is for economic reasons, because very few people are going up for rolling the kind of money you'd have to roll on a new process. Since cellulose to ethanol is going to be very difficult to justify at those intermediate stages that develop the demonstration stage. It might be only a fifty or a hundred tonne a day facility, we're going to have to try and

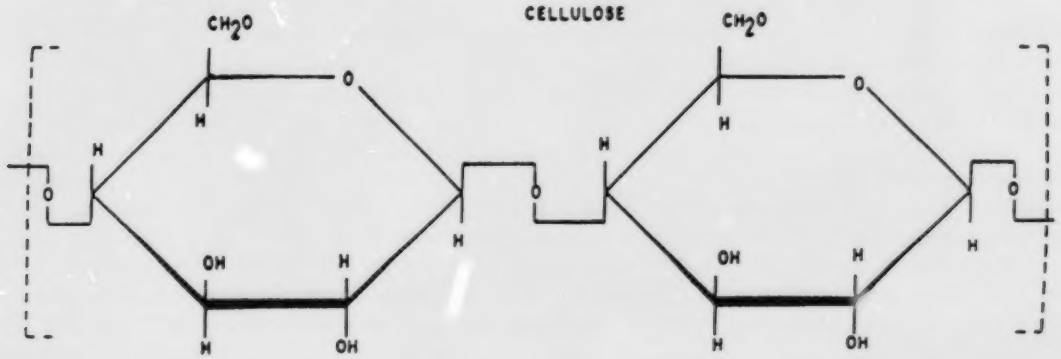
work out - we, our company, or whoever brings this technology to commercial fruition - is either going to have to have the deep pockets of an oil company or work out some way, some marketing strategy to finance that first run plant. I think the most likely would be around some types of high end by-product markets, either for the lignin materials that I discussed or the pento-sugars. Lignin can go into some of the higher end markets that have been demonstrated. It could make an immediate stage demonstration plant quite viable and set the stage and demonstrate the technology for very large scale implementation.

Thank you.



ETHANOL/OIL COST COMPARISON





DILUTE ACID HYDROLYSIS

by

DR. PER ASSARSSON
ST. LAWRENCE REACTOR
MISSISSAUGA, ONTARIO

Thank you very much, Doug. Well, I can add to the international list, Winnipeg, now.

What I thought I would do over the next twenty minutes or so, is to go through our company's development of a dilute acid hydrolysis technique that we've started to develop about ten years ago. It is a technique that we developed in terms of a true plug flow reactor technique. We started in a very small fashion back in 1976-78 and after a couple of years we were lucky to get funding from St. Lawrence Starch, and in that environment, we could develop the technique and have access to plant condition, and that is the kind situation which you are really, truly looking for when you're developing new technology. How do you, as was pointed out by the previous speaker, how do you get to the commercial line quickly. Well, you need that critical step to get into a plant situation to prove your point.

We spent approximately, as I said, five or six years to develop this type of technology before we actually said that we had a technique that we could go out in the commercial world and sell to the industry. I'd like to emphasize something which is sometimes very much overlooked in this case, and that is by taking the time to carefully develop the process technology, and making sure that you have your parameters correctly; that you have your scale-up conditions correctly, it is the difference between being successful in a commercial world or not successful in a commercial world. And I would just like to point out that due to this meticulous way of developing our technology, our company just completed the construction and running in of a 10 million gallon a year ethanol plant in Minnesota. We were the major process supplier to the plant, and we did it in record time of ten months, and it took us two weeks to run up the process to design capacity. So, it's a commentary, I think, on the time we spent prior to going out to the commercial world. And, I'd further like to point out that if that sort of model had been followed in the U.S., we would have had some more successful plants being built down there by some of the major engineering companies who, unfortunately, did not do their homework very well and left a fairly poor record in some of the plant areas.

So, what I thought I would do first then is to get - I have a few slides that will show how we have developed technique, the time frames and how we got them about getting to the commercial line. So, if I get the first slide.

The very first slide shows you the time frames and the temperature profiles involved in hydrolyzing starch bearing raw materials - it could be starch, it could be grains, it could be potatoes or rice or, as I said, any starch bearing material. So long as you can grind it down and slur it up,

we can put some acid in it, and they will all follow this sort of kinetic scheme that you see being plotted on this particular graph here. It takes us approximately two to three minutes to hydrolyze down the starch to a sugar solution that you can utilize as a fermentable substrate or you can utilize as a syrup in the food industry. It happens that tempertures hit about 155-165^{o} C. We are higher than what is normally used in the industry, but it allows us to make the conversion very, very quickly. As you can see, we have a heating up zone where we - the name of the game in the heating up zone is to get as much energy as possible into the process, and you have to overcome the so called viscosity envelope that is formed in there, and which is the primary reason why you operate under such pressures as say, 500 to 600 psi in the plug flow reactor. Once you've reached temperatures of about 130-135^{o} C, there's enough thermal energy into the chains that they can de-couple and they no longer bind into chainwise through hydrogen bonding. And, in fact, if you take out the sample at this point in time, then you still have fairly long chain storage, it is very fluid; you can pour it and handle as a very thin viscosity liquid. If you leave it standing for half an hour it will gel up on you and essentially become a cake that you can walk on. So, that shows you the importance of the temperature profiles that you got to necessarily obtain in this quick conversion technique. O.K., next slide.

This is a picture of a small pilot plant. It's sort of a pilot plant where we started to do our investigations, and it shows you the tubular reactor and the feeding mechanism in front of it. Now, next slide.

Here is a slide that focuses on the fact that you have several options when you do a commercial venture in terms of getting starch to ethanol. You can go on an enzymatic route; you can go on an acid enzyme route; or you can go an acid route. What I have tried to show here is that on the top of this particular graph, you start with the starch and you have the liquefying enzyme that will take you about an hour or so to get down to a dextrose equivalent of say, ten, or something like that. It then goes into a saccharification process step where you add the saccharifying enzyme and it then can take the residual oligomers of the starch and convert them to glucose and that glucose, of course, you can then ferment, in fact, very quickly because now if you wait long enough into saccharification step, something like say, forty hours or something like that, you get up to a glucose content of about say, 92-94%. And the fermentation that you can then carry out, if you do not have a condition of fibres in your particular stream, can be relatively rapid because you can then use a technique where you recycle the yeast and that means that the yeast population is fairly large and if the yeast population is large in your fermentation tank, then the fermentation gets over very quickly, anywhere from say, twelve hours to twenty hours, or something like that.

The second line there shows you a technique where you can either use the acid to liquefy or you can use the enzymatic process to liquefy, and the only difference there really is that it takes the acid route about 3-4 minutes and it takes the enzymatic route about an hour. But then you go into the saccharification step, in the middle there, and you may stay there for something like two hours or three hours, or something like that, so that you go to a dextrose equivalent of, say thirty or thirty-five. Not too high, because if you get too much glucose under condition of simultaneous

saccharification and fermentation (SSF), you tend to get run away fermentation, lots of foaming, etc. So you like to essentially be in the neighbourhood of a glucose count then say, of 20% or 25%. That is this particular middle process train there is normally utilized in the industry today. Now the SSF can be carried out either in batch form or fed batch form, or in a continuous batch form and the techniques for that are well known, and that's the sort of thing that we will ask any operator to suit his own needs and will build it to them.

The third line there is a technique that we have developed where we can use only acid in order to hydrolyze down to starch. And we do that by lowering the dry solids count to about 25%. We add a little bit more acid and we get up in temperature maybe five degrees more. And what happens is that we get conversions of the starch up to about 88-89% glucose. We have developed reversion paradox and they are the remaining 12 or so per cent that are in the fermentable substrate. Now those reversion paradox are in general are not fermentable so by all standards you would lose them. However, if you recycle the distillage and you go through the fermentation, and you take two-thirds of the distillage into the process again and dispose of one third of distillage, you then can recapture the dimers because they cleave down again. The reversion products being mainly dimers, and so that you can perpetuate the acid hydrolysis that way, and once you go through the arithmetic over this, and over several cycles, you'll find that you get down to efficiencies of approximately utilizing 96%, or 95 or so per cent, of the starch in the fermentation process.

Now, the thing I wanted to point out about this third level process train is that you can actually make that an extremely rapid process. As I said it will take the hydrolysis about 2-3 minutes and if you have a clear substrate with no fibre in it, you can then load up your fermenters with yeast, say 6 to 8 grams per litre of yeast, or something like that, and your fermentations can essentially get over in anywhere from twelve to sixteen hours. So you have a mechanism here by which you can do very, very fast fermentations. You can even do faster ones if you listen to the next speaker. Zymomonas affair - if you couple that together with this then you have an organism that can work several times faster than yeast. These are the type of processes that one can commercially view today in the industry. Next slide.

Well, there's a few little lines in this, but let me just take time out to explain what it is that we are seeing here. Because it is important, because this is the fingerprint of a hydrolysis, saccharification and fermentation in one slide. If we start, as you see on an X-axis there, there's a number of arrows that we have plotted for this particular fermentation trial, and on the Y-axis we have plotted the per cent fermentables. What essentially that means is, we are following the starch either as starch, as oligomers, which is highers, or we're following the glucose, dimers and trimers. So when you start out at time zero there we have actually gone through the two minutes of hydrolysis and we're into two or three hours of saccharification, and what you're finding there is that the highers keep dropping on you, the glucose rises up to about 30% at that particular point, and the dimers and trimers, as you see, increase. You're now looking at the staple line - about the four hour line. As that is pumped into the fermenter, you can then see how very quickly the glucose,

the G there, disappear. In eight hours, that's gone in this type of fermentation. This is an SSF fermentation. The dimers take a little bit longer, because that is an in between product that is made from the highers and goes through into the glucose, and the trimers in a similar manner.

But, very quickly, say at the twenty hours the whole process is now dependent upon the kinetics of the saccharifying enzyme in the fermentation pack. It's the saccharifying enzyme that controls the fermentation from there on in. So, of course, at this point, if you want to speed it up and even if it costs you a little bit, you can throw in another handful of enzyme, and you can get it going a little faster. Another sort of noteworthy thing here is, if you look at the production of ethanol, you can see that it goes asymptotically to a final level or final concentration in there, and similarly, of course, on the highers or oligomeric starch is asymptotically disappearing. Now, what happens in real life, in the plant is that you don't ever go to completion in this type of situation because somewhere along the line it will cost you much more to sit and wait for the last one or two per cent to ferment over to ethanol. And you can much better utilize that time by cutting the fermentation, sending over to the beer still, wait for some of the unfermentables that you have had come back in the back set, might be utilized 40% to 50% or something like that, and so you get some of it back that way. Particularly if the plant manager knows that he's got to produce ethanol in a hurry, he keeps cutting it sooner and sooner we end the process.

Another noteworthy point here is - look at the glycerine production. That happens within the first ten hours, the glycerine production and it's coupled together mainly through the growth mode of the yeast, and that's when it is produced, and after that it stays relatively constant.

But anyway, this particular, what I call a fingerprint of a fermentation, is really how you can view a fermentation and how you have to have your kinetics right in order to develop the engineering around it and the process characteristics that you want to design around.

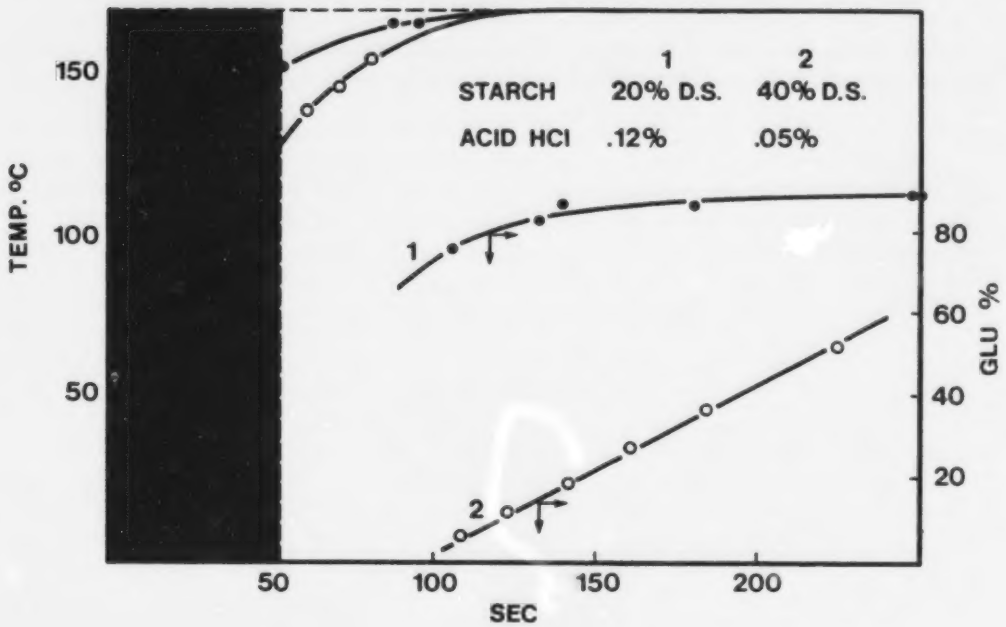
O.K., next slide. That shows you a duel enzyme process. I don't have to go through it because it is in absolute similarity to the other one and the same process does occur in it. I mentioned this business of the third process train, but we have a very high glucose - acid hydrolyzed glucose fermentable substrate and this is typically the type of fermentation times that it will take, depending upon the amount of yeast that you have available. The glucose is about, as you see on the fermentable, is about 88-87% and it's gone when you have 20 grams per litre, your reactions cease, but eleven hours if you have six - it's gone about twenty-two hours. And you can see that the dimer profile at 'D', at about 10% level stays the same and it's not affected by the fermentation.

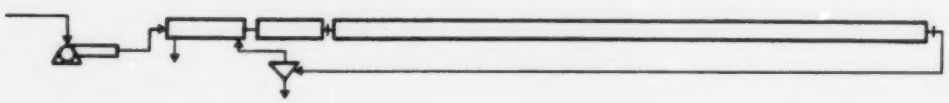
I'm going to cut the talk right here in terms of describing the hydrolysis of starch bearing raw materials. I should mention to you that our company also is very heavily involved in the hydrolysis - the dilute acid hydrolysis of ligno-cellulosic feed stocks, and we have done a fair amount of work - Doug has been trying to sponsor much of it - in terms of converting agricultural residues as well as wood substances. At present time, we have a pilot plant fully dedicated to this particular endeavour

together with the Weston Group in Toronto.

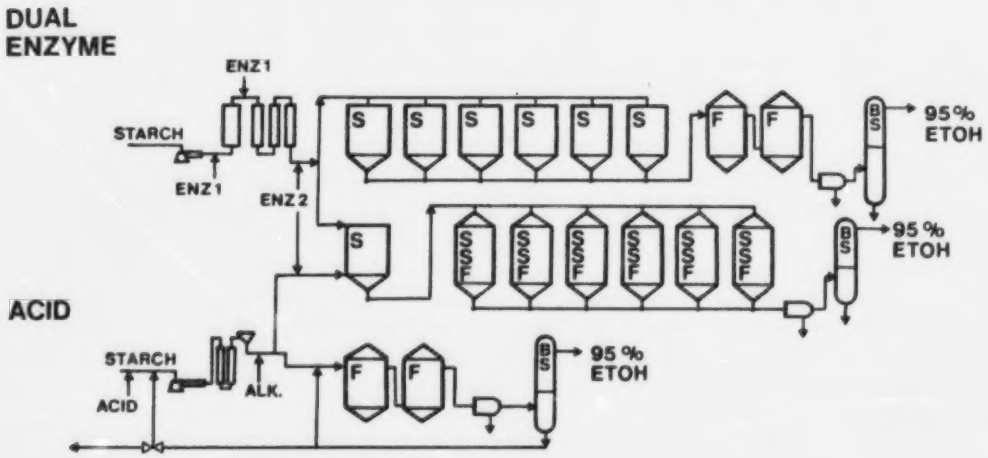
That's roughly what I was going to tell you, and I'll end it here, and maybe answer a question or two.

STARCH SLURRY TEMPERATURE AND GLUCOSE FORMATION VS. RESIDENCE TIME





PROCESSING OF STARCH TO ETHANOL



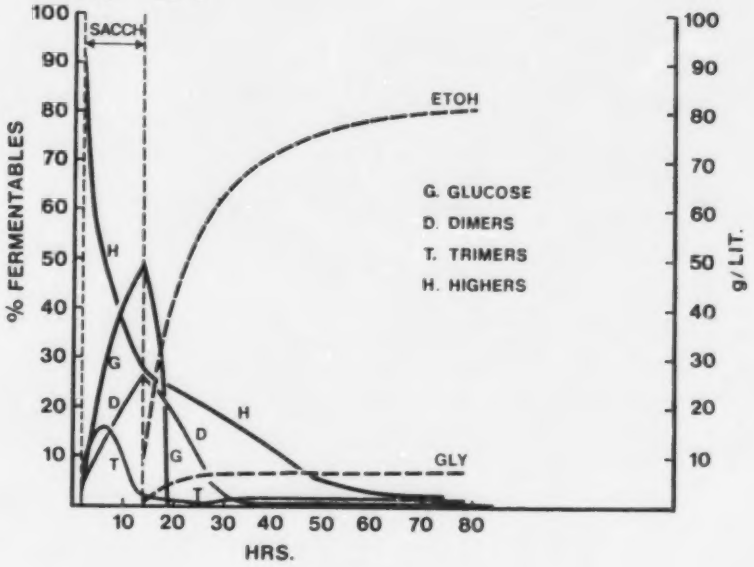
SUGAR COMPOSITIONS FROM MAXIMUM LIQUEF. + SACCH.

DUAL ENZYME PROCESS		ACID PROCESS		
			1ST PASS	RECYCLE 2:1
GLU	94-95%	GLU	88-89%	96.0%
DI	5-6%	DI	10-11%	3.5%
TRI	-	TRI	1%	.5%

HYDROLYSIS & FERMENTATION OF CORN STARCH

DUAL ENZYME PROCESS

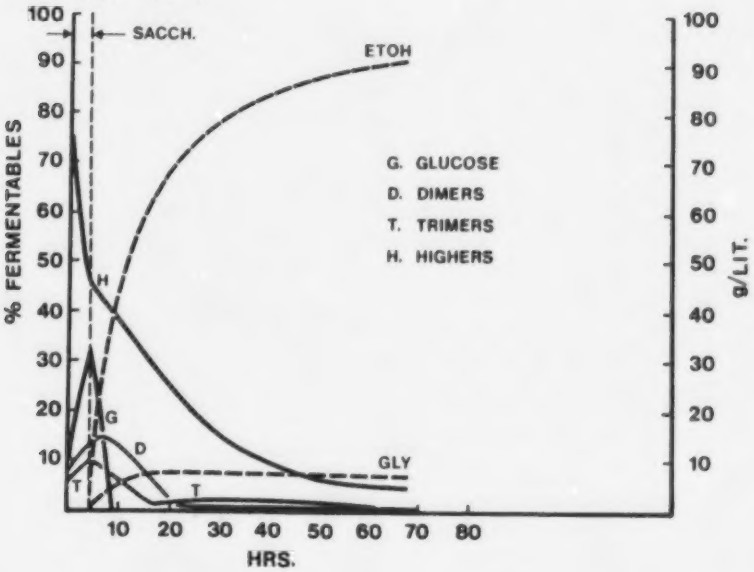
D.S. ~ 20%



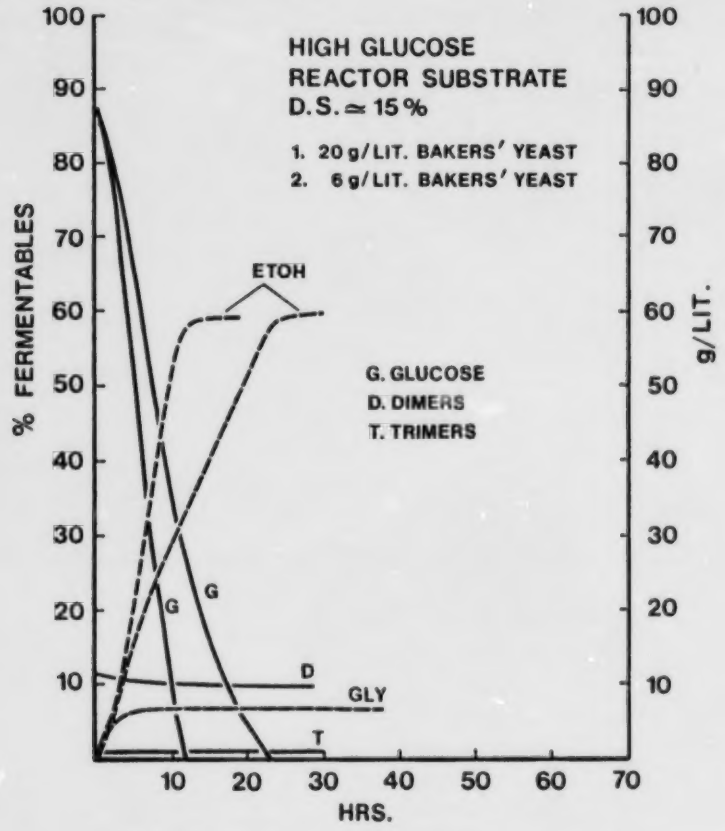
HYDROLYSIS & FERMENTATION OF CORN STARCH

ACID PROCESS

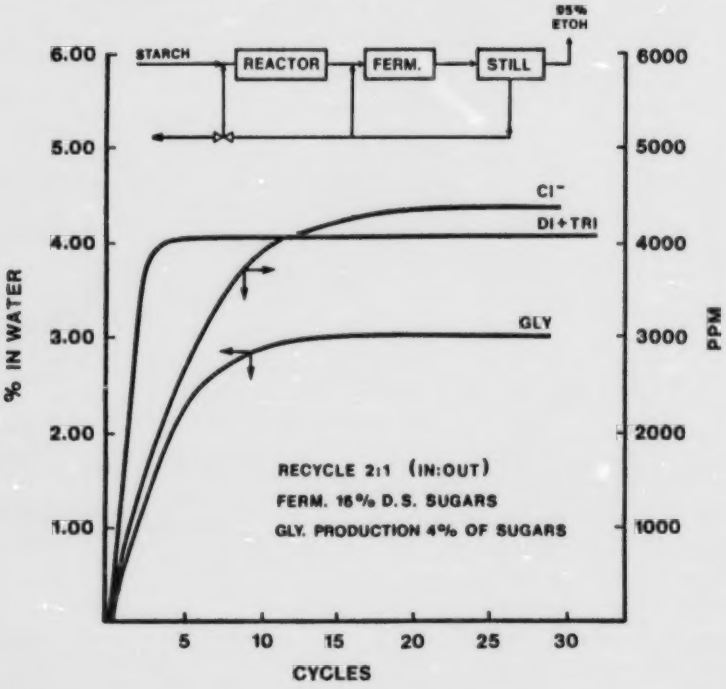
D.S. ~ 20%



HYDROLYSIS & FERMENTATION OF CORN STARCH



FERMENTATION RESIDUALS VS. RECYCLES FOR ACID CONVERTED STARCH SUBSTRATES



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DEPARTMENT OF CHEMICAL ENGINEERING
AND APPLIED CHEMISTRY

RECENT DEVELOPMENTS IN ETHANOL FERMENTATION OF GRAIN AND WOOD SUGARS

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CANPAC '88
WINNIPEG, MANITOBA, OCTOBER 4, 1988

ABSTRACT

We have been able to show significant advantages in combining saccharification and fermentation of grains such as barley and wheat starch B. Yields of ethanol are in the 450 to 500 L/tonne range, and the total time from liquefaction to completion of fermentation is 14 hours compared to 50 hours when these 2 stages are separate. When S. diastaticus Labatt 164A is used instead of S. cerevisiae in fermentation, the amount of glucoamylase required is reduced to half, but at some cost in ethanol yield and slower fermentation. When Zymomonas mobilis is used to ferment saccharified wheat starch B, fermentation time is reduced from 24 hours to 18 hours, and yields of ethanol are 7% higher than when S. cerevisiae is used. When saccharified wheat starch B is fermented with immobilized microorganisms in the continuous dynamic immobilized biocatalyst bioreactor (CDIBB), the time is much reduced further, almost quantitative yields of ethanol being produced in 3 hours with bakers' yeast and in less than 1 hour with Z. mobilis. Alcohol concentrations were 7.5 and 7.7 % by volume, and yields were 475 and 518 L/tonne with the 2 microorganisms, respectively.

The CDIBB is described and compared with recent Japanese pilot plants for immobilized cell fermentation. Its performance with various substrates is reported. Raw molasses at 195 g/L sugar and with substantial suspended matter was fermented completely by bakers' yeast in less than 4 hours. Saccharified wood cellulose was fermented by Z. mobilis in the CDIBB in 20 minutes.

There are strong parallels between grain fermentation and wood fermentation: SO2 steep, dual enzyme saccharification for example, and also significant differences: the presence of xylose in wood, and the strong inhibition of cellulase enzyme by cellobiose compared with the weaker inhibition of glucoamylase by maltose. These differences are overcome by using different yeasts. In fermenting saccharified cellulosics, a mixed culture of a cellobiose-fermenting yeast and a xylose-fermenting yeast give excellent results, 360 to 400 L/tonne of wood or agresidues being obtained. The xylose fermenting yeast requires adaptation lto wood hydrolysates for most effective action, and a continuous adaptation system is described. Scanning electron micrographs and isoenzyme analysis strongly suggest thaty the yeast adapted under stress has changed over from a haploid to a polyploid form.

The mode of action of cellulase enzymes is described. Genes for 4 of the 5 enzymes have now been inserted into S. cerevisiae. Also the transformation of Z. mobilis with the starch saccharifying enzymes is being planned, in the expectation of achieving rapid single stage starch or whole grain saccharification-fermentation to ethanol.

When we look to grain or cellulosics for fuel ethanol supply, we recognize a massive scale problem. It would require 32 to 100 plants large by Canadian standards across Canada to supply 10 to 20% of our motor fuel demand. Such a cluster megaproject would cost $3 to $6 billion. It would give an enormous boost to agriculture, adding diversification to present farm operating strategies, and to forestry, as well as be welcome addition to the business of many supplying industries. It would generate 50,000 to 100,000 permanent jobs, give government substantial welcome revenue, and contribute heavily to clean air in our cities.

This presentation is a review of recent work in our laboratory at the University of Toronto, some of it in collaboration with Allelix, and some with Bio-Hol.

Figure 1 shows our yields of ethanol from various substrates: wheat starch B, whole barley, wheat chaff, corn stover, pine and aspen chips. Grains give 450 - 500 L/tonne, the cellulosics 350 - 400 L/tonne.

Figure 2 compares separate saccharification and fermentation with combined, simultaneous saccharification-fermentation. The most significant difference is in processing time: total about 60 hours for separate and 15 hours for simultaneous saccharification and fermentation.

Figure 3 shows the benefit when S. diastaticus is used in starch fermentation. The amount of glucoamylase required is reduced to half, although the fermentation is a little slower and the yield not quite as good as when S. cerevisiae is used.

Figure 4 compares fermentation of saccharified wheat starch B by ordinary bakers' yeast and by Zymomonas mobilis. Yields are 490 vs 524 in favour of the bacterium, a gain of 7%, and fermentation time cut from 24 to 18 hours. The Zymomonas, as Hugh Lawford has pointed out so often, makes ethanol while the yeast is just reproducing itself. In this next Figure 5 they are compared in a continuous fermenter in which the microorganisms are immobilized. Again the Zymomonas has the higher yield, 9% higher this time, and the shorter fermentaion time: 3 hours for the common yeast and less than 1 hour for the Zymomonas.

The continuous dynamic immobilized biocatalyst bioreactor (CDIBB) used in those runs is remarkably efficient in fermenting sugary materials in high yields, very rapidly. The molasses used here in Figure 6 was plain, raw molasses, 195 g/L sugar, completely fermented in less than 4 hours; the other substrates were faster. This molasses had a fair bit of suspended solids, but that did not bother the fermenter. Here are 2 views of the CDIBB. In Figure 7 the red yeast immobilized on the rotating discs is transforming a cheap chemical into an expensive one. Here is a diagram showing the simple setup. Figure 9 shows the packing, a set of separated rotating discs not installed very well so that their irregularity exerts a welcome pumping action. Our largest CDIBB so far is about 60 cm long. Here is a view of a Japanese pilot plant to hopefully do the same thing, but not as well. And here is a different pilot plant. They are different in that the former immobilizes the yeast in beads, and the latter on film. But they are both static, whereas ours is dynamic. The cost of either Japanese pilot plant is more than my laboratory will spend during its entire life span. Rich people, these Japanese. Also wedded to innovation and risk-taking.

The parallel between hydrolysis and fermentation of grain and of wood is very close, as shown in Figure 10. In both cases an SO2 steep is followed by dual enzyme saccharification, then fermentation and distillation. Since grain fermentation has been with us for many centuries, the purpose of this figure is to demystify wood fermentaion. Grain ethanol yields are better, some 25% better. Other differences are shown in Figure 11. One is that maltose is a weak inhibitor of enzyme activity, while cellobiose, the dimer of glucose that comes from cellulose in the same way that maltose comes from starch, cellobiose is a strong inhibitor of enzyme activity. To deal with that we use cellobiose-fermenting yeasts that ferment cellobiose directly to ethanol, preventing end-product inhibition. Also wood has xylose, of which starch has none, and common yeast will not ferment xylose. We are fortunate in having a stable of xylose-fermenting yeasts, which we use in our fermentations.

Those yeasts have the property of adapting to xylose under stress, even in tough conditions such as prehydrolysates or spent sulphite liquor. In Figure 12 you see the enormous effect of adaptation. The yeasts become much larger (Figure 13) and the fat yeasts are bundles of enzymes (Figure 14): 3 alcohol dehydrogenases compared to only 1 in the parent strain, and so on. Several enzymes important in glucose fermentation as well as xylose fermentation are present in much larger quantity in these adapted yeasts. Figure 15 shows a continuous adaptation system, as suggested to us by Prof. Walter Steiner. In this photograph, the yeast is learning to live with an aspen prehydrolysate, a nasty mixture of inhibitors. Prof. Steiner's system works.

Figure 16 shows that end-product inhibition prevents completion of sugar production. The inhibitor is the dimer cellobiose, and the addition of the enzyme cellobiase helps, but then the glucose itself becomes the inhibitor. But by using a cellobiose-fermenting yeast, in this case Brettanomyces clausenii, which also ferments glucose, the cellobiose is removed from the solution by conversion to ethanol and the end-product inhibition is overcome. In working with wood or other cellulosics we use a mixed culture of one of our xylose-fermenting yeasts and a cellobiose fermenter.

There are several good cellobiose fermenters (Figure 17). In this way we have been able to avoid the use of cellobiase in saccharification (Figure 18), since the yeast supplies it. Here are the results of pilot plant prehydrolysis of coniferous wood and of aspen, then simultaneous saccharification-fermentation with our mixed yeast culture, and quite good yields of ethanol.

We have had good success with wood hydrolysates in our CDIBB (Figure 19). Saccharified aspen cellulose was completely fermented in 20 minutes. We have observed these almost explosive fermentations also in batch (Figure 20) with saccharified wood cellulose. The acid hydrolysates take longer, because of inhibitors.

We have recently come to understand more about cellulase enzymes, learning particularly from the Finnish group under Jonathan Knowles at VTT in Espoo. Figure 21, from one of their recent papers, shows that solid, native cellulose is attacked only by two cellobiohydrolase enzymes, which liquefy cellulose to cellodextrins and cellobiose, much as alpha amylase does with starch. Then two endoglucanases process the cellodextrins to cellobiose, and a 5th enzyme, cellobiase or beta glucosidase, completes the saccharification to glucose. A group at Allelix including Nigel Skipper and Raymond Wong, in collaboration with the microbiology department at the University of British Columbia, has succeeded in inserting genes for 4 of these 5 enzymes into ordinary yeast. It was our pleasure to use the newly created yeast to saccharify aspen cellulose. Genetic engineering has promise for us (Figure 22).

Figure 23 indicates some new technology, here, and coming. These innovations will bring down the price of fuel alcohol by simple, direct conversion of grain and cellulosics to ethanol.

There are those who are skeptical about the future of alcohol as a transportation fuel because of the magnitude of the supply problem. They need have no fear. Figure 24 illustrates the scale problem and shows that for 10% ethanol in gasoline in Canada, we need 32 good sized alcohol plants, perhaps large for Canada but only one-quarter the size of the 8 largest US plants. We can build 32 plants: the Brazilians have 550 of them. If we want to follow the Brazilian lead and supply hydrated alcohol as the sole fuel for half of our automobiles, we need 160 plants, one-third the Brazilian number. Figure 25 presents the concept of a cluster megaproject with 200 to 300 ethanol plants of various sizes spread across Canada. Cheap at $6 billion, half a dozen submarines, and look at the benefits (Figure 25 ctd), tremendous diversification of agriculture and numerous supply industries, 50,000 to 100,000 new, permanent jobs, clean air in our cities, can we afford not to do it?

The supply of large volumes of natural gas to Western Europe by the Soviet Union has relieved the pressure on oil supply and oil prices, which will be stable for the next few years. This gives us the breathing space we need to plan and implement our renewable, permanent transportation fuel supply, so that we wont be caught short when the crunch comes, as come it must.

ETHANOL YIELDS, L/TONNE

	WHEAT STARCH B	WHOLE BARLEY	WHEAT CHAFF	CORN STOVER	PINE CHIPS	ASPEN CHIPS
S & F	492	450	354	388	372	346
S S F		452	403		360	384
YEAST	S.c.	S.c.	P.s.R + C.L.	P.s.R + B.c.	P.s.R + B.c.	P.s.R + B.c.

S & F = SACCHARIFICATION FOLLOWED BY FERMENTATION
S S F = SIMULTANEOUS SACCHARIFICATION-FERMENTATION

Figure 1

COMPARISON OF
SACCHARIFICATION & FERMENTATION WITH
SIMULTANEOUS SACCHARIFICATION-FERMENTATION

EXAMPLE: WHOLE BARLEY

RESULTS:

S & F: TOTAL TIME 61 HOURS, 450 L ETHANOL/TONNE, 9.0 % v/v
S S F: " " 13 ", 452 L ETHANOL/TONNE, 8.9 % v/v

CONDITIONS:

S & F: 0.1% ALPHA AMYLASE, pH 6.8, 85C, 45 MIN, THEN
0.1% GLUCOAMYLASE, pH 5.0, 50C, 48 HOURS
(SUGARS, 147 G/L)
YEAST § 12 G CELLS (DRY)/L + NUTRIENTS, 30C, 12 HOURS.

S S F: 0.1% ALPHA AMYLASE, pH 6.8, 85C, 45 MIN, THEN
COOL TO 37C, pH 5.0, 0.1% GLUCOAMYLASE + YEAST § 12 G CELLS (DRY)/L + NUTRIENTS, 12 HOURS

Figure 2

COMPARISON OF S. CEREVISIAE AND S. DIASTATICUS LABATT 164A

WHOLE BARLEY, S S F

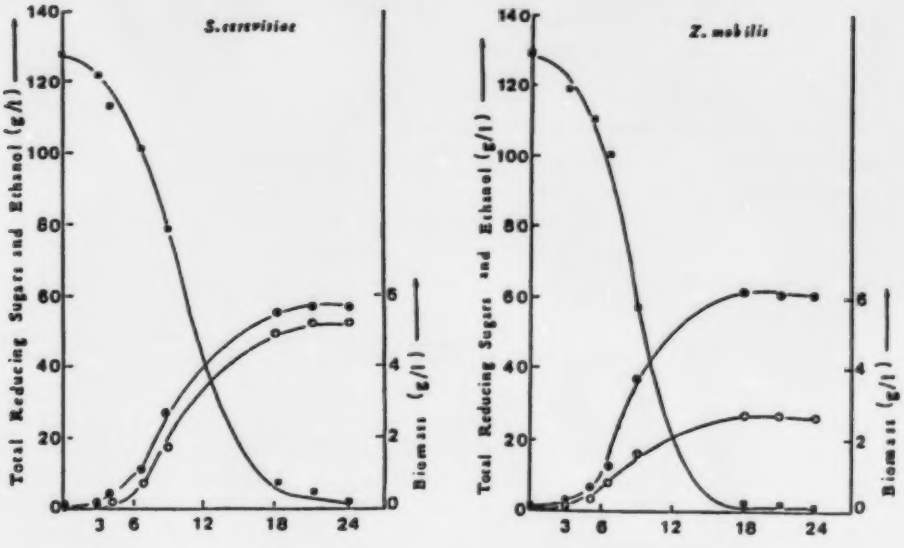
	S. CEREVISIAE	S. DIASTATICUS 164A	
GLUCOAMYLASE, %	0.1	0.05	0.1
ETHANOL			
L/TONNE	452	412	437
% v/v	8.9	8.1	8.6
TIME, HOURS	12	24	24

CONCLUSION:

S. DIASTATICUS LABATT 164A RDUCED GLUCOAMYLASE BY ONE-HALF, BUT AT SOME COST IN LOWER ETHANOL YIELD AND SLOWER FERMENTATION.

Figure 3

COMPARISON OF ZYMOMONAS MOBILIS AND SACCHAROMYCES CEREVISIAE
WHEAT STARCH B, SACCHARIFICATION & FERMENTATION



	S. CEREVISIAE	Z. MOBILIS
ETHANOL		
L/TONNE	490	524
% V/V	7.3	7.7
TIME, HOURS	24	18
FINAL CELLS, G/L	5.2	2.4

Figure 4

CONTINUOUS FERMENTATION BY IMMOBILIZED
S. CEREVISIAE OR Z. MOBILIS

	S. CEREVISIAE	Z. MOBILIS
ETHANOL		
L/TONNE	475	518
% V/V	7.3	7.7
TIME, HOURS	3	0.9
PRODUCTIVITY, G/L-H	20	53
THROUGHPUT, VOLUMES/DAY	5	18

Figure 5

PERFORMANCE OF CONTINUOUS DYNAMIC IMMOBILIZED BIOCATALYST BIOREACTOR

AT 56 gl^{-1} CELL LOADING IN REACTOR

Substrate	Sugar Concentration (gl^{-1})	Sugar Utilization (%)	Ethanol in effluent (gl^{-1})	Ethanol Productivity ($gl^{-1}h^{-1}$)	Retention time (h)	Yield g ethanol/ g sugar
			Saccharomyces cerevisiae			
Glucose	54	90	24.3	15.2	1.6	0.50
Cane molasses	195	90	83.0	23.0	3.6	0.48
Corn wet milling waste	115	98	56.0	22.4	2.5	0.50
Wheat-Starch B	140	96	59	20.2	3	0.46

Figure 6

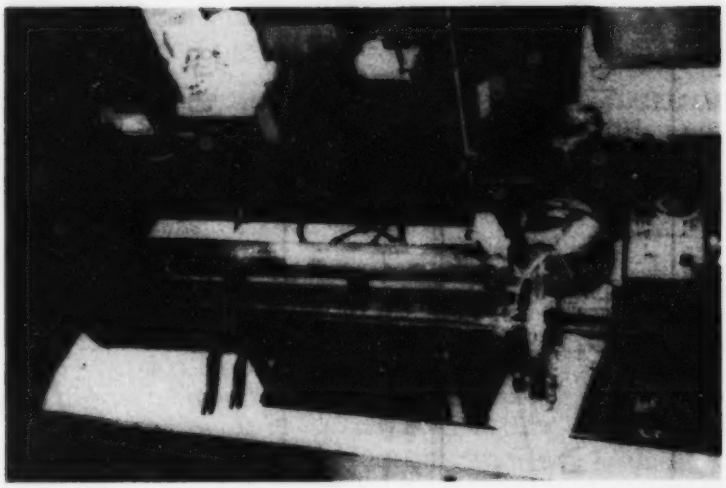
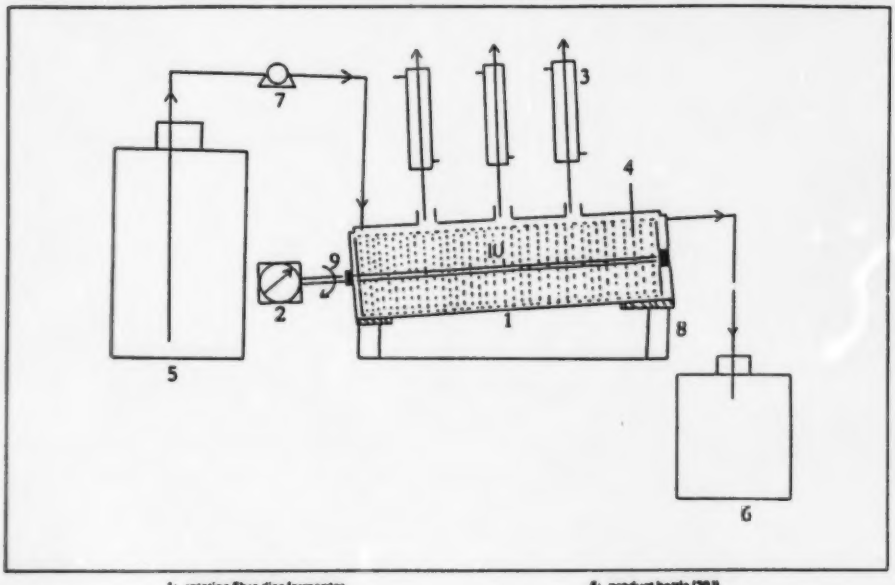


Figure 7

PAREKH, PAREKH, and WAYMAN. FERMENTATION OF WOOD-DERIVED ACID HYDROLYSATES



1: rotating fibre disc fermenter
2: constant speed motor
3: condenser
4: thermometer
5: feed bottle (20 l)
6: product bottle (20 l)
7: peristaltic pump
8: stand
9: central shaft
10: fibre discs

The total fermenter volume, including headspace, is 3.4 l, and the liquid volume to overflow is 2.0 l.

Figure 8

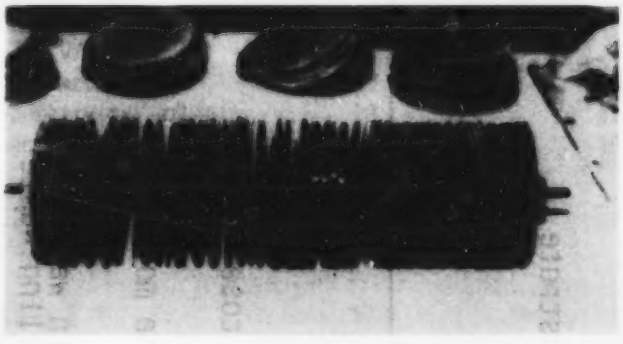


Figure 9

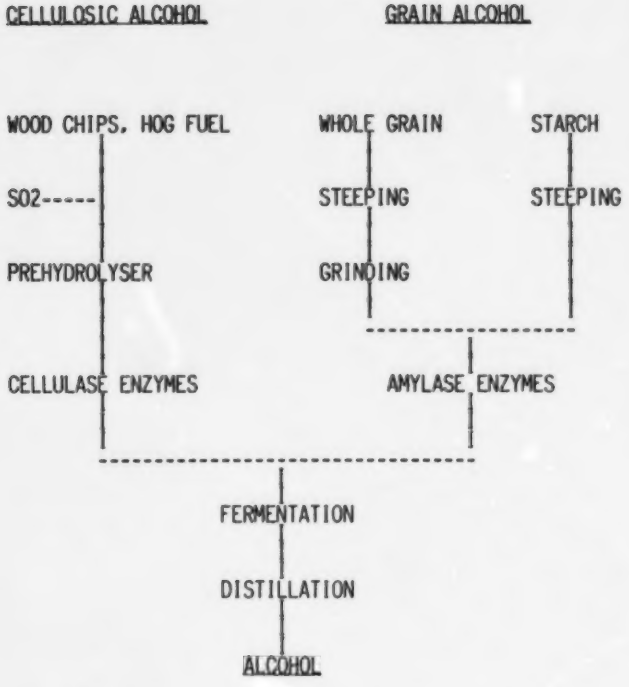


Figure 10

GRAIN & WOOD SACCHARIFICATION & FERMENTATION DIFFERENCES

SACCHARIFICATION: GRAIN: MALTOSE IS WEAK INHIBITOR OF COMPLETE SACCHARIFICATION
WOOD: CELLOBIOSE IS STRONG INHIBITOR OF COMPLETE SACCHARIFICATION

ANSWER: USE CELLOBIOSE-FERMENTING YEAST FOR WOOD S & F OR S S F

FERMENTATION: GRAIN: USE COMMON BAKERS' YEAST
WOOD: HAS XYLOSE, WHICH COMMON YEAST WILL NOT FERMENT

ANSWER: USE XYLOSE-FERMENTING YEAST

SIMULTANEOUS SACCHARIFICATION-FERMENTATION:
GRAIN: USE COMMON BAKERS' YEAST
WOOD: USE MIXED CULTURE OF CELLOBIOSE-FERMENTING AND XYLOSE-FERMENTING YEAST

Figure 11

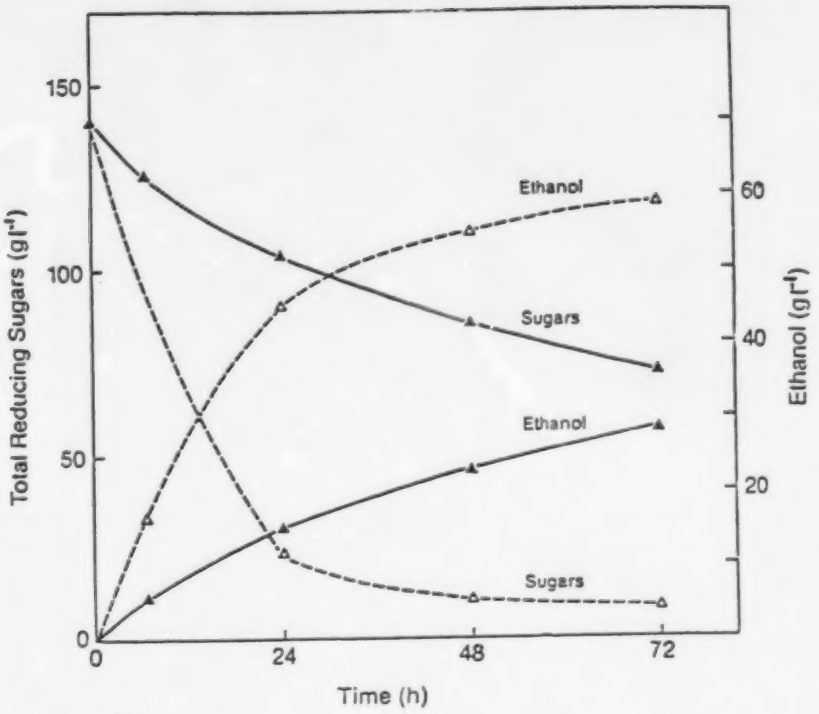


Figure 12

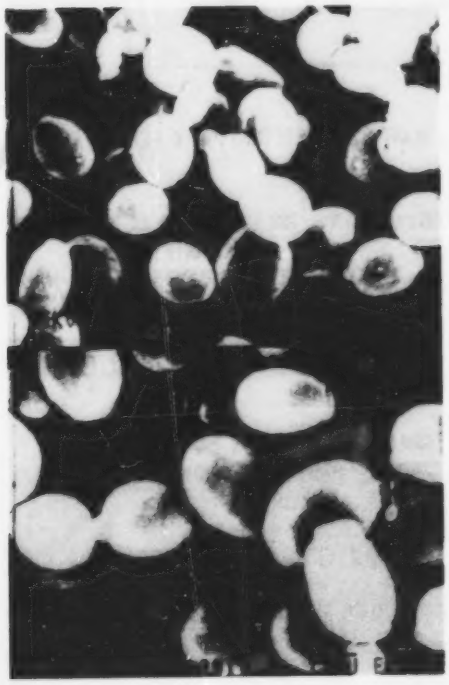


Figure 13

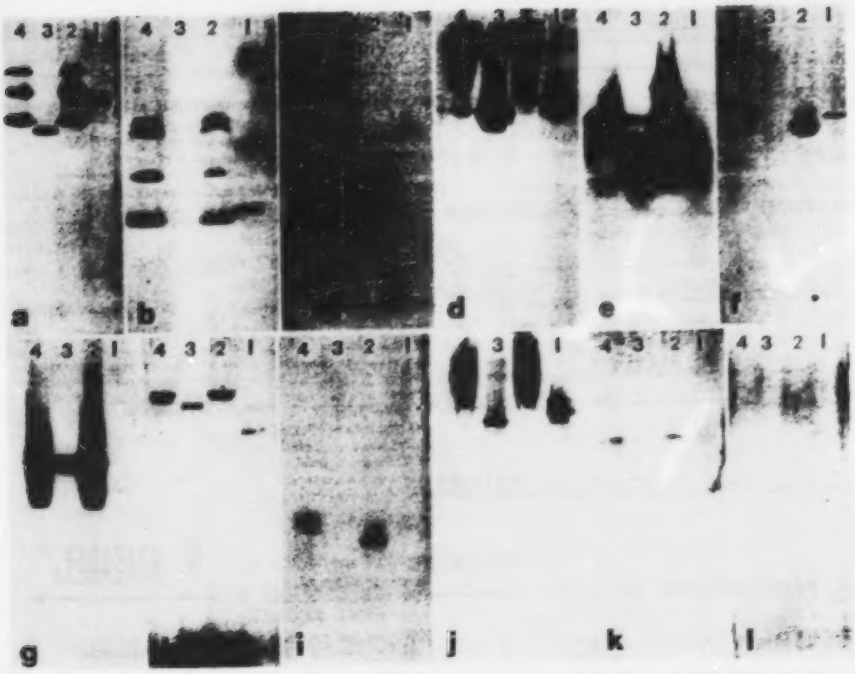


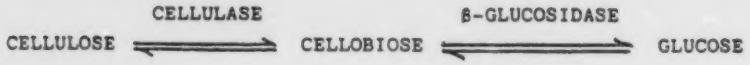
FIG. 1. Isoenzyme banding patterns for (*a*) alcohol dehydrogenase, (*b*) aldolase, (*c*) esterase, (*d*) glucose-6-phosphate dehydrogenase, (*e*) hexokinase, (*f*) isocitrate dehydrogenase, (*g*) malate dehydrogenase, (*h*) peroxidase, (*i*) phosphoglucomutase, (*j*) 6-phosphogluconate dehydrogenase, (*k*) succinate dehydrogenase, and (*l*) tetrazolium oxidase of *Candida shehatae* (1), R-1 (2), *Pichia stipitis* (3), and R-2 (4). The R strains exhibited similar banding patterns for all the enzymes tested.

Figure 14

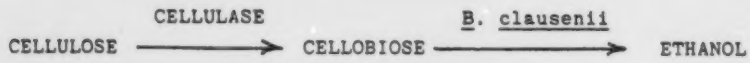
Figure 15

FIGURE 16 ENZYME HYDROLYSIS AND SIMULTANEOUS SACCHARIFICATION-FERMENTATION

1. ENZYME HYDROLYSIS



2. S.S.F., CELLULOSE



3. S.S.F., WOOD, AGRICULTURAL RESIDUES

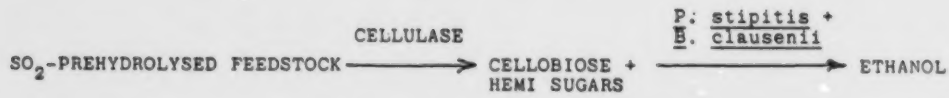


Table 1. Fermentation of cellobiose, 26 g/L, anaerobic, 30 C

Yeast	Residual Cellobiose	Ethanol 12 h	Ethanol 24 h	Yield g ethanol /g sugar consumed
	g/L	g/L	g/L	
Brettanomyces clausenii NRRL Y 1414	0	11.1	13.5	0.51
Candida lusitaniae ATCC 34449	1.2 (12 h)	13.0	13.1	.51
Torulopsis wickerhamii ATCC 36540	0.56	12.0	13.0	.50

Figure 17

MIXED YEAST CULTURES, SIMULTANEOUS SACCHARIFICATION-FERMENTATION

	CONIFEROUS WOOD	ASPEN
PILOT PLANT PREHYDROLYSIS	STAKE, 208C 2 MIN, 2.6% SO2	WENGER, 200C 45 SEC, 2.5% SO2
ETHANOL		
L/TONNE	360	384
G/G SUGAR	0.45	0.46

CONDITIONS: CELLULASE + HEMICELLULASE, NO BETA-GLUCOSIDASE
12% ENZYME ON FIBRE, 12% SOLIDS, 38C, pH 4.8, 48 HOURS
MIXED CULTURE: PICHIA STIPITIS R + BRETTANOMYCES CLAUSENII, CELL DENSITY 16 G/L, DRY WEIGHT

Figure 18

Table 1. Fermentation of hydrolysates of aspen and pine cellulose by immobilized cells of *Z. mobilis* in a continuous dynamic immobilized biocatalyst bioreactor

Feedstock	Glucose Concentration Feed g/L	Glucose Concentration Effluent g/L	Glucose Conversion %	Ethanol g/L	Retention Time h	Yield g ethanol /g sugar consumed	Volumetric Productivity g/L-h
Enzyme Hydrolysate							
Aspen	50	2.0	96	24	0.33	0.50	73
Acid Hydrolysate							
Aspen	48	3.4	93	22	4.2	.49	5.2
Pine	50	2.5	95	23	2.3	.49	10

Figure 19

Table 2. Comparative performance of *Z. mobilis* and *S. cerevisiae* in batch fermentation of acid and enzyme wood cellulose hydrolysates

Feedstock	Microorganism	Potential Glucose g/L	Fermentation Time h	Ethanol g/L	Yield g ethanol /g sugar consumed	Volumetric Productivity g/L-h
Enzyme Hydrolysate						
Pine	*Z. mobilis*	50	0.25	24	0.48	94
Aspen	*Z. mobilis*	52	0.25	25	.49	100
Acid Hydrolysate						
Aspen	*Z. mobilis*	50	7	24	.48	3.5
"	*S. cerevisiae*	50	16	24	.47	1.5
Pine	*Z. mobilis*	50	4	25	.49	6.2
"	*S. cerevisiae*	50	10	24	.48	2.4

Figure 20

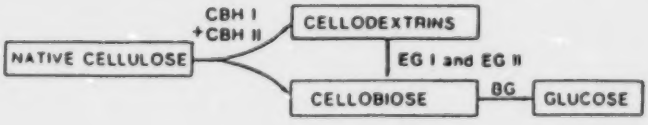


FIGURE 21. Suggested scheme for the enzymatic hydrolysis of cellulose. Enzymes: CBH, cellobiohydrolase; EG, endo-β-glucanase; βG, β-glucosidase (8).

GENETIC ENGINEERING FOR BETTER FERMENTATION

WE NOW HAVE *Saccharomyces cerevisiae* TRANSFORMED WITH 4 OUT OF THE 5 CELLULASE ENZYMES. THIS *Scee* YEAST TOGETHER WITH ADDED BETA-GLUCOSIDASE SACCHARIFIED ASPEN CELLULOSE, BUT PRODUCTION OF THE ENZYMES WAS TOO LOW FOR S S F.

FOR CELLULOSICS, OUR AIM IS FOR S S F WITH *S. cerevisiae*, WHICH NEEDS HIGHER ENZYME OUTPUT, AND TRANSFORMED WITH THE 5TH ENZYME.

FOR GRAIN, OUR AIM IS FOR *Zymomonas mobilis* CONTAINING THE GENES FOR ALPHA AMYLASE AND GLUCOAMYLASE, FOR S S F.

Figure 22

NEW TECHNOLOGY

NOW:

1. HIGH SPEED CONTINUOUS FERMENTER
2. CELLULOSICS: SIMPLE 2-STEP PROCESS, PREHYDROLYSIS THEN DIRECTLY TO S S F
3. A BETTER GRAIN GRINDER: THE SZEGO MILL FOR WHOLE GRAIN OR WET GRINDING

COMING:

1. IMMOBILIZED ENZYMES AND FERMENTATION IN C D I B B
2. GENETICALLY ENGINEERED MICROORGANISMS FOR S S F OF GRAIN AND CELLULOSICS

Figure 23

CANADIAN ANNUAL MOTOR FUEL CONSUMPTION

UNIT = MILLION L/YEAR

GASOLINE	32,000
GRAIN OR WOOD-BASED SIZE PLANT	100
FOR 3% ETHANOL IN GASOLINE = 10 PLANTS	1,000
FOR 10% ETHANOL IN GASOLINE = 32 PLANTS	3,200
FOR 50% HYDRATED ALCOHOL SUPPLY = 160 PLANTS	16,000

THE 8 LARGEST U.S. PLANTS AVERAGE 400 MILLION L/YEAR

Figure 24

THE CLUSTER MEGAPROJECT

1. 50 TO 150 ETHANOL PLANTS ALL ACROSS CANADA
2. CAPACITIES 20 TO 150 MILLION LITRES/YEAR EACH
   TOTAL OUTPUT 5,000 TO 10,000 MILLION LITRES/YEAR
   = 10 TO 20% OF GASOLINE DEMAND
3. COST $20 TO $40 MILLION EACH
   TOTAL COST $6 BILLION
4. TIME FRAME: PHASE IN OVER 10 YEARS, THEN INCREASE TO MEET DEMAND
5. FEEDSTOCKS:
   - SURPLUS GRAIN
   - DEDICATED GRAIN
   - FOREST INDUSTRIES WASTES
   - DEDICATED ENERGY PLANTATIONS
   - MUNICIPAL SOLID WASTE
6. SUPPLIER INDUSTRIES:
   - AGRICULTURE
   - AGRICULTURAL EQUIPMENT
   - CHEMICAL
   - CHEMICAL EQUIPMENT
   - INSTRUMENT MANUFACTURERS
   - STEEL
   - PLASTICS
   - CONSULTING ENGINEERS
7. R & D:
   - AGRICULTURE
   - FORESTRY
   - BIOCHEMICAL ENGINEERING
   - BIOTECHNOLOGY
8. ENVIRONMENT:
   - CLEANER AIR
   - GETS THE LEAD OUT OF GASOLINE
   - IMPROVES GLOBAL CO_2 BALANCE
9. BY-PRODUCTS:
   - BEEF
   - EDIBLE OIL
   - PROTEIN
10. EMPLOYMENT:
    - CONSTRUCTION: 10,000 MAN-YEARS FOR 10 YEARS
    - OPERATION: 50,000 TO 100,000 PERMANENT JOBS

Figure 25

24

ZYMOMONAS - A SUPERIOR PROCESS ORGANISM FOR MOTOR FUEL ALCOHOL PRODUCTION

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ABSTRACT

Cost sensitivity analyses for fuel alcohol production have indicated that appropriate criteria for fermentation performance assessment are (i) product yield or the efficiency of converting the feedstock into alcohol, (ii) volumetric productivity, and (iii) final ethanol concentration. Theoretical yield calculations were based both on efficiency of conversion of carbohydrate feedstocks to fermentable sugar as well as the efficiency of conversion of sugar to ethanol with the maximum yield (100% total process efficiency) being 2.9 US gallons undenatured anhydrous ethanol per bushel of corn (60% starch content). Fermentation is generally considered a low productivity and capital intensive approach to producing organic chemicals. Most fermentation ethanol is produced by traditional batch fermentations using yeast.

The effectiveness of a combination of various biological and engineering strategies for process improvement related to the production of fermentation fuel alcohol (ethanol) are discussed. The *bioengineering approach* to improving process productivity has involved operating the fermentors continuously at higher cell densities with systems employing cell retention or recycle. The *biological approach* to process improvement addresses the characteristics of the process organism. For the past 10 years, my laboratory has been investigating the potential of the ethanologenic, mesophilic bacterium, *Zymomonas mobilis* as an alternative to yeast for fuel alcohol production.While both organisms grow similarly and are about equally sensitive to ethanol toxicity, comparative studies revealed a number of distinct differences with respect to both efficiency (yield) and fermentation kinetics. Direct comparative fermentation performance trials with commercial feedstocks (starch hydrolysate) revealed that benefits to be derived through the substitution of yeast by *Zymomonas* include the potential for (i) a 10% increase in process yield, which is significant considering the feedstock represents about 70% of the overall production costs, and (ii) a very substantial increase in volumetric productivity. Unlike yeast, ethanol production by *Zymomonas* is not strictly coupled to growth. The specific rate of ethanol production (q_p) exhibited by a non-growing culture of *Zymomonas* is at least 25 times faster than a non-growing yeast culture. Work in this lab has shown that environmental factors, both chemical and physical, affect the regulation of energy metabolism in *Zymomonas* and process strategies to exploit this unique characteristic have been described. In high cell density, continuous systems (operating with cell recycle or retention, at equivalent cell mass loading to yeast), the superior kinetic properties of *Zymomonas* can be exploited to affect about a five fold improvement in vol. productivity.

Comparative performance assessments have been performed with different genotypic and phenotypic variants and these investigations have yielded important information both with respect to the choice of organism and optimal operating conditions. The patented **"Bio-Hol Processes"** for motor fuel alcohol production incorporate the high-performance and high-efficiency characteristics of *Zymomonas* in significant improvements of traditional yeast-based fermentations with respect to both product yield, concentration and productivity. The Bio-Hol Process produces a beer with an ethanol concentration in excess of 12% with a carbohydrate conversion efficiency of 97%. This R&D was part of a contract between Bio-Hol Developments (a joint venture between George Weston Ltd. and St. Lawrence Reactors Ltd.) and The University of Toronto.

INTRODUCTION

Whereas the economics associated with the production of potable alcohol is sufficiently insensitive to cost and whereas there is little incentive in the industry for change or process improvement, the present economic environment relating to the production of fermentation fuel alcohol (specifically ethanol) for use either as an "octane booster" or gasoline extender ("gasohol") provides the necessary inducement for developing new and more efficient fermentation processes. Although the fuel alcohol industry has developed out of the technology-base of the alcoholic beverage industry, "taste" is no longer a constraint to process design or efficiency.

Criteria For Process Performance Assessment

The three most important factors arising out of cost sensitivity analyses for motor fuel alcohol production by fermentation are shown in the Table below and these factors have been adopted as our criteria in assessing process (fermentation) performance with a view to improving efficiency through a combination of both bilogical and engineering strategies.

FACTORS OF TECHNO-ECONOMIC IMPORTANCE IN ASSESSING ETHANOL FERMENTATION PROCESSES

[1]	*PRODUCT YIELD* (efficiency of converting the feedstock to ethanol)
[2]	*VOLUMETRIC PRODUCTIVITY* (amt. ethanol / unit volume / unit time)
[3]	*FINAL PRODUCT CONCENTRATION* (conc'n of ethanol exiting from fermentation system)

Theoretical Maximum Yield:
How Many Gallons of Ethanol Per Bushel of Corn ?

Since the cost of fermentable carbohydrate feedstocks (eg. corn, milo, barley) represents by far the major cost for the production of fermentation ethanol, the question of process yield (the efficiency with which the process microorganism is capable of converting added carbohydrate into ethanol) becomes a very important one - where a 1% increase in yield can mean as much as 700,000 extra gallons (US) of undenatured 200 proof alcohol per year based on the same rate of feedstock utilization for a high-capcity production plant. The generally accepted industry standard for yield of ethanol from corn is 2.5 US gallons absolute ethanol per bushel (56lbs) of No. 2 yellow corn (USDA, 1980).

In a recent survey of reported yields in the fermentation ethanol industry in North America, I discovered that there are perhaps as many different ways of calculating "yield" as there are fuel alcohol producers. Much of the confusion and misunderstanding comes from the lack of definition of terms involved, so much so that comparisons in yield from one plant to the next are seldom meaningful, or even justified, because the calculations are not based on equivalent parameters. This gives rise to many untenable and false claims as well as unreasonable expectations on the part of both owners and operators.

FACTORS CONTRIBUTING TO PRODUCT YIELD
and PROCESS EFFICIENCY

[A] *PRIME FACTORS*
- EFFICIENCY OF SACCHARIFICATION PROCESS
- EFFICIENCY OF FERMENTATION PROCESS
- EFFICIENCY OF ETHANOL (ALCOHOL) RECOVERY PROCESS

[B] *OTHER FACTORS OFTEN NEGLECTED IN DESCRIBING OVERALL PROCESS EFFICIENCY*
- MOISTURE CONTENT OF GRAIN FEEDSTOCK
- CONTENT OF FERMENTABLE MATERIALS
- DEGREE OF HYDRATION OF FINAL PRODUCT (95% versus 99.9%)
- "ETHANOL" AS DISTINCT FROM "ALCOHOL" (product contains other alcohol by-products, fusel oils)
- DENATURED versus UNDENATURED PRODUCT (account for 5% difference by vol.)

* measured as gallons of alcohol per bushel of corn

When assessing such yield improvements it is wise to do so with a knowledge of the target one is ultimately shooting for. Figure 1 illustrates the way in which one would calculate the value of the maximum theoretical yield (ie. if all processes operate at 100% efficiency). Assuming that the corn is 60% starch, the maximum alcohol yield is 2.89 US gals. absolute ethanol per bushel. The accepted yield of only 2.5 gals. represents an overall processing efficiency of about 87% .

The biochemical equation and the materials balance for the ethanol fermentation process operating at 100% conversion efficiency is given below:

sugar ⟶ ethanol + carbon dioxide + heat

Molar balance

$$C_6H_{12}O_6 \longrightarrow 2[C_2H_5OH] + 2[CO_2]$$

Weight balance *

100 lb ⟶ 51.1 lb + 48.9 lb

* This stoichiometric relationship is the basis for the factor of 0.511 (associated with the fermentation part of the process for the conversion of starch to alcohol) shown in Fig. 1 for the calculation of the theoretical maximum alcohol yield per bushel of corn.

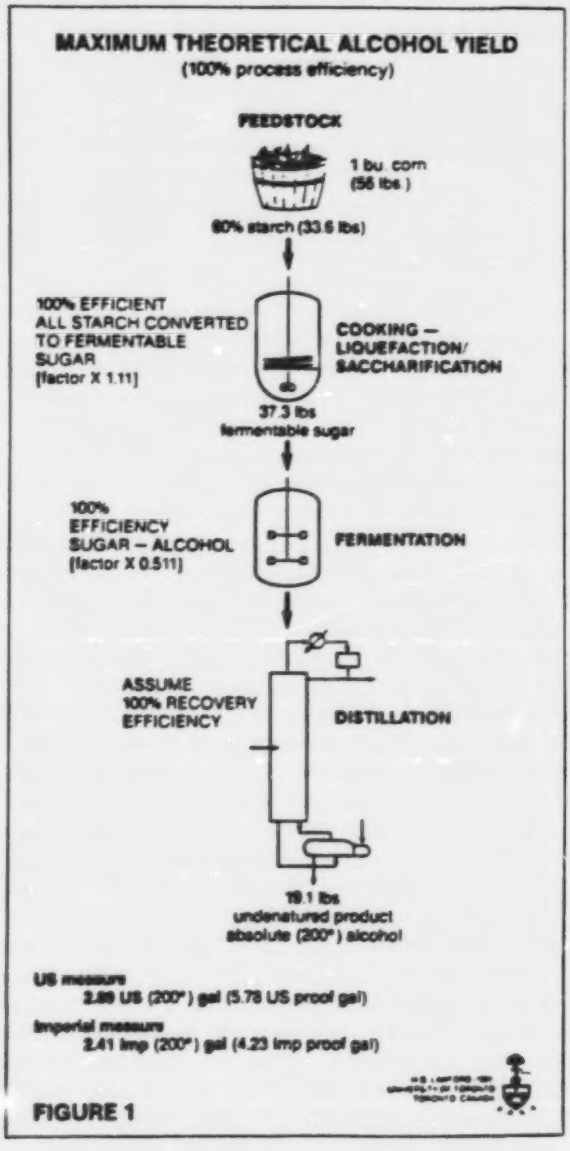


FIGURE 1

Figure 2

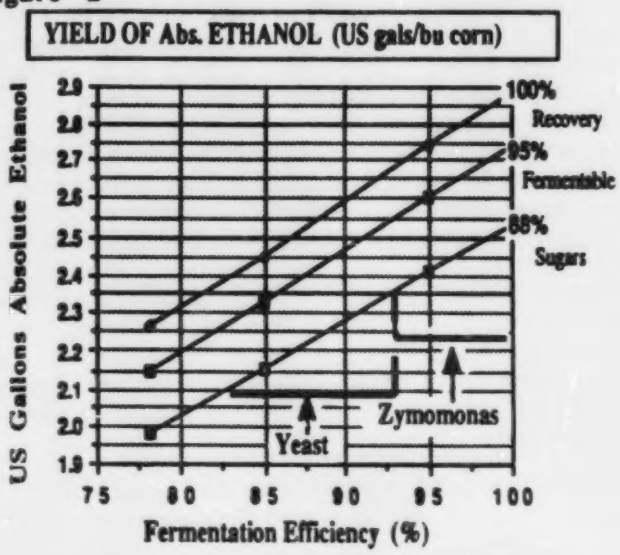


Figure 2 represents a graphic illustration of the potential for yield improvement and considers yield improvements both in terms of the efficiency of starch recovery and conversion to fermentable sugars (based on an average starch content of 60% or 33.6 lbs starch per bushel of corn) as well as the fermentation efficiency of the process microorganism in the conversion of fermentable sugar (glucose) to ethanol.The enzymic saccharification process is only about 95% efficient in producing glucose from starch and an additional 7% loss is generally experienced by wet millers in the processes of starch separation and recovery - these overall process efficiencies are represented in Figure 2 by the 95% and 88% recovery lines respectively. Accordingly the maximum yield to be anticipated in these operations would be 2.74 and 2.53 US gals. of undenatured absolute ethanol per bushel of corn respectively. The industry bench mark of 2.5 gallons anhydrous ethanol per bushel of corn with yeast would indicate that either there is 100% recovery of fermentable carbohydrate or, if there is a 5% loss of fermentable carbohydrate, that the yeast converts the sugar to ethanol with an efficiency of about 92% - this does not correlate well with literature data for yeast fermentations [2-8,12,13].However, more recent yield values from some of the newer large-scale fuel alcohol plants in the US where the process is continuous and operated at high cell-density with cell recycle, suggest that under these operating conditions, yeast is capable of achieving conversion efficiency in this higher range (range shown in Fig. 2).

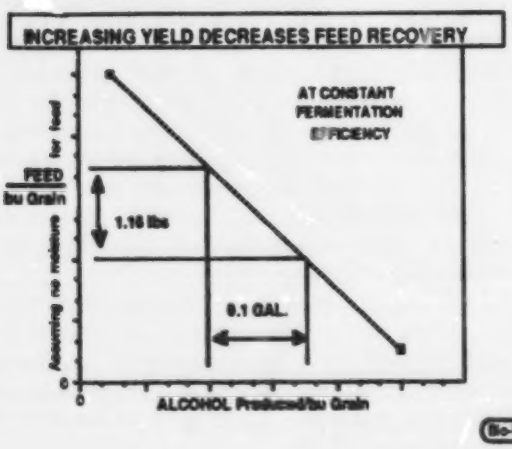
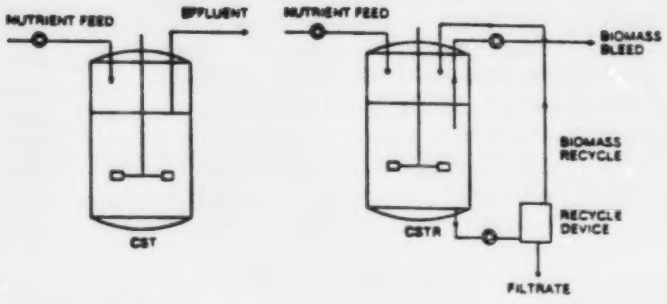


Figure 3



STRATEGIES FOR PROCESS IMPROVEMENT

1. INCREASED PRODUCTIVITY - The Engineering Approach to Process Improvement

Compared to chemical processes, fermentation is generally considered a low productivity and capital intensive approach to producing organic chemicals. Most of the world's supply of fermentation ethanol is produced by traditional batch fermentations using yeast. One of the first approaches to process improvement involved operating the fermenters in a continuous mode (Fig. 3) with a consequential three fold increase in productivity from 2 to 6 g EtOH/L/hr [1].

Operating continuously at higher cell densities using continuous cell recycle reactors (Fig. 3) was another effective means of greatly increasing the productivity. A single-stage CSTR with cell recycle operating at high cell loading (50-80 gDW yeast/L) has an ethanol productivity of 30-40 gEtOH/L/hr [2-4] and several different technologies relating to cell recycle or cell retention (eg. immobilized cell reactors) have been reported in the literature [5-9].

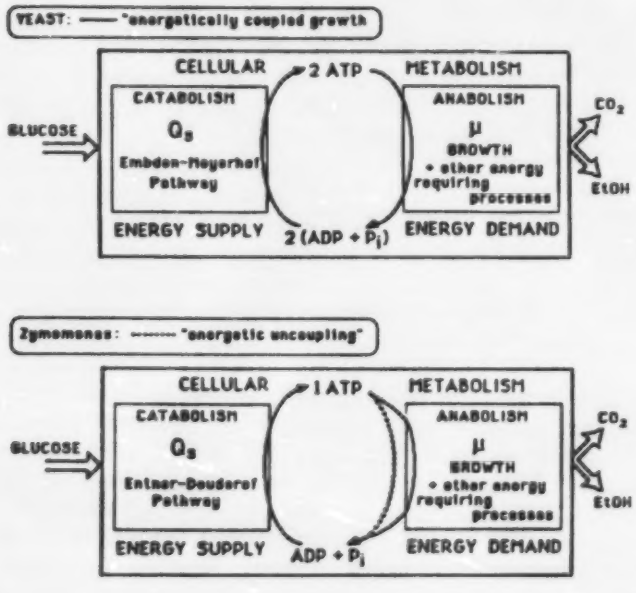
2.0 The Biological Approach to Process Improvement

Yeast is traditionally regarded as the bio-catalyst in ethanol fermentations and although most fuel alcohol fermentation processes currently utilize well known strains of brewer's or baker's yeast, recent research has focussed on the search for new varieties and alternative ethanologenic organisms tailored to the specific needs of the emergent fuel alcohol industry. Notably, interest in the possible use of the bacterium *Zymomonas* surged following the publication of a review in 1977 which indicated that while some species of this genus had been identified as the ethanol producers in some natural tropical beverage fermentations, the potential for industrial ethanol production by this organism had been overlooked [10]. A program of comparative experimental fermentations with type strains of yeast and *Zymomonas mobilis* were commenced in 1978 in collaboration with scientists at the Weston Research Centre (Geo. Weston Ltd.,Toronto)[11,12].

While these organisms grow anaerobically at similar rates and are both equally sensitive to ethanol toxicity, these comparative studies revealed a number of distinct differences with respect to both efficiency (yield) and fermentation kinetics. Unlike yeast, *Zymomonas* does not require small amounts of oxygen for growth and is therefore a more suitable candidate for continuous fermentations of the type required for economic production on an industrial scale.

2.1 Increased Yield with *Zymomonas*

Zymomonas exhibits a product yield ($Y_{p/s}$) which is significantly higher than yeast. Average steady-state values for $Y_{p/s}$ of 0.48 gEtOH/g glu (94% theoretical) and 0.43 gEtOH/g glu (84% theoretical) have been reported in comparative studies with *Zymomonas* and yeast respectively [12,13]. Hence one of the more significant improvements to be derived from the substitution of *Zymomonas* for yeast in either a batch or continuous process (operating without cell recycle or cell retention) is by virtue of an approx. 10% improvement in yield or fermentation efficiency. This is particularly significant because the feedstock represents an estimated 70% of the overall cost of producing fermentation ethanol. This increase in yield represents an extra quarter gallon of anhydrous ethanol per bushel of corn (Fig. 2).



2.2 Increased Productivity with *Zymomonas*

Volumetric Productivity (g/L/hr) = $q_p \cdot X$

where q_p is the (specific rate of ethanol production) and X is the cell density (g/L)

$$q_p = q_s \text{ (specific rate of glucose utilization)} \cdot Y_{p/s}$$

Table 1 shows comparative kinetic values (q_s) for yeast and *Zymomonas* . A growing culture of *Z. mobilis* exhibits about a 4 to 5 fold higher specific rate of glucose utilization compared to yeast (Table 1). Since the volumetric productivity is proportional to specific rate of ethanol production(q_p) which is in turn proportional to the product yield ($Y_{p/s}$), in high cell density, closed-type continuous systems (operating with cell recycle or cell retention, at equivalent cell loadings - Fig. 3), the superior kinetic properties of *Zymomonas* can be exploited to affect about a five fold improvement in volumetric productivity. This has been confirmed in independent experimental systems with productivities in the range 120-200 gEtOH/L/hr reported (Table 2) [14,15].

Table 1 Comparative Steady-state Fermentation Kinetics for Yeast and *Zymomonas*

Physiological State	Specific Rate of Glucose Utilization [a] q_s [g glu/ g cell (DW)/ hr]	
Specific growth rate μ (hr^{-1})	Yeast	*Zymomonas*
Non - Growing (m_e)	0.06 [b]	1.5 - 3.5
Growing (q_s)		
(a) Slowly μ = 0.06	0.8 [b]	3
(b) Fast (μ_{max})	1.7 - 2.1 [c]	8 - 10

[a] The specific rate of glucose utilization (q_s) was determined in steady-state chemostat culture as a function of the specific growth rate (μ) equivalent to the dilution rate. The value for the maintenance energy coefficient (m_e) was derived by extrapolation to μ = o in plots of q_s vs. D.

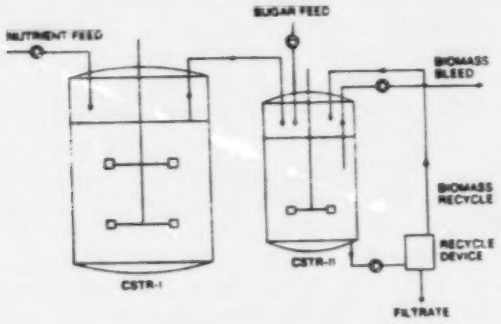
[b] data taken from ref. 16 ; [c] data from ref. 12

Sugar utilization, and consequently ethanol production, by yeast is almost completely a growth related process; the specific rate being almost 35 times faster in the case of growing yeasts than non-growing yeast (Table 1). Maintenance metabolism by non-growing yeasts accounts for some alcohol production but the rate is, by comparison, extremely slow [16]. This well regulated or conservative type of glucose metabolism in yeast translates in practical terms into a requirement for relatively high cell mass loadings in order to achieve an acceptable rate of fermentation by non-proliferating yeast. Energy metabolism is much less controlled or regulated in *Zymomonas* and supply is not obligatorily coupled to the energy demands of the anabolic processes. This difference is manifested in the value for the maintenance energy coefficient whereby the specific rate of ethanol production exhibited by a non-growing culture of *Zymomonas* is at least 25 times faster than a non-growing yeast culture. Environmental factors, both chemical and physical, have been implicated in affecting the maintenance energy coefficient in *Zymomonas* and process strategies have been reported to exploit this unique characteristic [17,18].

2.3 Genetic Approach to Process Improvement with *Zymomonas*

This approach to increasing process productivity attempts to improve the performance of the process organism by attempting to correct a recognized weakness or deficiency as, for example, the alcohol tolerance. Ethanol toxicity limits the final product concentration to about 10% (w/v) in batch fermentations and 5% in single-stage continuous processes. Claims have been made regarding the improved performance of a putative alcohol-tolerant mutant of *Z. mobilis* (strain ZM481)[22] although these have recently been disputed [23].

Figure 4 Two-stage Cascading CSTR's with Recycle to 2nd Stage



Kinetics of continuous ethanol production by *Z. mobilis* ATCC 29191 in a two-stage CSTR system with cell recycle on the second stage.

	Process Parameters					
	D (hr^{-1})	X (g/l)	P (g/l)	VP (g/l/h)	$Y_{p/s}$ (g/g)	Q_p (g/g cell/h)
Stage I	0.220	3.75	53.70	11.81	0.46	3.15
Stage II	0.533	44.91	101.87	30.75	0.49	0.68
Overall	0.178	-	101.87	18.13	0.48	-

3.0 THE "BIO-HOL PROCESS"

In 1981, **Bio-Hol Developments** was formed as a joint venture between George Weston Limited and the Ontario Energy Corporation with the major objective of demonstrating the conversion of lignocellulose to a variety of products, including fuel alcohol, at pilot plant scale. Although the ***Bio-Hol Process*** was designed and the pilot plant equipped for pretreatment of a variety of lignocelluloic feedstocks, a full description of this unit of the overall process is beyond the scope of this paper which focusses on the fermentation aspects of the overall process. The *Bio-Hol Process* is described in detail elsewhere[20,21].The evaluation of the various lab processes which had been designed to exploit the specific advantages of *Zymomonas* as a highly efficient alcohol producing organism, required that the pilot plant be designed to be flexible and adaptable into a number of continuous process configurations. Pilot scale testing of *Zymomonas* fermentation technologies commenced in 1983 using glucose containing media in reactors ranging in size from 28 to 3,000 L. In September 1986, St. Lawrence Reactors Ltd., a subsidary company of St. Lawrence Starch Co. (Mississauga), replaced Ontario Energy Corporation in the joint venture and the patented SLR plug-flow acid convertor was used to generate high quality fermentable substrates for the continuous flow *Zymomonas* -based fermentors.

Table 2 Comparative Operational Process Parameters for Continuous Ethanol Fermentations with *Zymomonas mobilis*

System Configuration		Total System Residence Time (hrs)	[Ethanol] Volume %	Volumetric Productivity (g EtOh/L/hr)	Process Yield (% theoretical)	Ref.
A. Single CSTR		4.8	7.1	12	92	12
B. Single CSTR with floc mutant *		1.1	7.8	58	98	15
C. Single CSTR + cell recycle		0.3	5.5	151	90	15
D. Two-stage cascade CSTRs (no recycle)	lab	23.3	11.6	4	97	This work
	pilot plant		12 - 13	4 - 5	88 - 98	20, 21
E. "Bio-Hol Process" Two-stage cascade CSTRs (+ recycle)	lab	5.6	12.9	18	95	19, 24
	pilot plant	6.8	12.0	14	97	20, 21

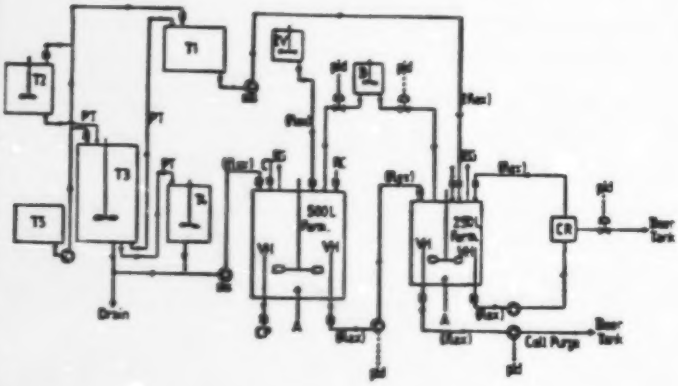
Process parameters are not necessarily maximal values. Yield was calculated on input sugar concentration. Residence time was based on >95% conversion of sugar feed to alcohol. *Zymomonas mobilis* ATCC 29191 was used in all cases - * the flocculating strain was isolated as a spontaneous mutant of *Z. mobilis* ATCC 29191.

3.1 Process Design Considerations

The final product concentration is limited in a single stage continuous process (Figs.3) due to the requirement for cell growth. Since growth is almost completely inhibited at ethanol concentrations greater than 6% (v/v), the final concentration of ethanol which can be achieved in a single stage CSTR is about 6% (Table 2) and this is independent of whether yeast or *Z. mobilis* is used (assuming an equivalent sensivity of each microorganism to ethanol toxicity).

A two-stage system was used in order to achieve a final beer with an alcohol concentration >6% (v/v) - beer enrichment being accomplished in the second stage; however, the productivity of such a system is comparatively low with a overall residence time of about one day (Table 2). The two-stage system exploits the capacity of *Zymomonas* for high rates of ethanol production under non-growing conditions (2nd stage) where the fermentation efficiency approaches 100% conversion of added fermentable carbohydrate to ethanol. *Zymomonas* produces only trace amounts of other fermentation by-products (organic acids, glycerol, fusel oils). Figure 5 is a schematic representation of the design chosen to increase the productivity of the overall process. A two-stage design permits optimization of product formation in both growth and non-growth environments and allows full exploitation of the unique capacity of *Zymomonas* for relative high rates of ethanol production when not growing. By employing cell recycle to the 2nd stage, the overall residence time was reduced by about 70% (Table 2).

Figure 5 Design of Bio-Hol Developments' Pilot Plant Fermentation Unit (not to scale)



Legend:

IV	Innoculum development vessel	A	Aeration facility
B	Base vessel	VH	Variable height standpipe
	Transfer pump	EG	Exhaust gas
ms	Manual set	CR	Cell recycle device
pid	PID control	I	Inoculation port
(flex)	Flexible line	CT	Cell transfer port
	Quick connect fitting	RC	Recycle port
	Control valve	CP	Cell purge facility
PT	Pressure transfer		

The patented, high-efficiency, Bio-Hol fermentation process [19,19a] is a continuous cascade system with propagation of *Z. mobilis* in the first stage and product enrichment (>12 vol.%) in the absence of cell growth in subsequent stages [24] and is operated with cell recycle for increased productivity [Fig. 5; Table 2].

In addition to the two-stage cascade system for alcohol enrichment just described, Bio-Hol Developments has developed other high-performance processes using phenotypic and genoptypic variants of *Zymomonas*.For example, flocculating mutants of *Z. mobilis* (15) have been developed for use in a CSTR with about a 5 fold increase in vol. productivity (compared to a CSTR with freee cells) and alcohol at about 8 vol. % (Table 2 - In B). Bio-Hol's continuing strategy for process improvement is the subject of five (5) US patents pending all of which are due to issue this year. At the recent 10th Biotechnology Symposium for Fuels & Chemicals (Gatlinburg, TN - May,1988) we presented the results of our trials in direct side-by-side comparisons of commercial yeast and *Zymomonas* (ATCC 29191) in a commercial corn wet-milling operation using hydrolyzed corn starch with all necessary nutrients being provided by the corn steep water and recycled process stillage (25). These tests confirmed the superior nature of *Zymomonas* over yeast for motor fuel alcohol production

Some of the advantages of using *Zymomonas* which have not been addressed in detail in this work include the fact that this organism survives under simialr conditions to yeast (pH, temp. etc.) except that it does not require small amounts of oxygen for growth as does yeast. Nor does it produce higher alcohol (fusel oils) in significant yield and this impacts favourably on the recovery (distillation) process. *Zymomonas* does not produce very much glycerol which makes the processing of by-product DDG easier.

There are however, some areas for further R&D and these are (i) broadening the carbohydrate utilization profile of *Zymomonas* beyond glucose and sucrose, (ii) improving the ethanol, temperature and salt tolerance of the organism, and (iii) assessing nutritional aspects of DDG with *Zymomonas* instead of yeast for animal feed (eg. vitamin content, etc.). Finally, although theoretically there should be no more heat generated in the *Zymomonas* fermentation, because of the greater fermentation activity, it will be necessary to engineer efficient means for heat transfer in the proposed systems, especially at high cell mass loadings where the q_p is also relatively high.

ACKNOWLEDGEMENTS

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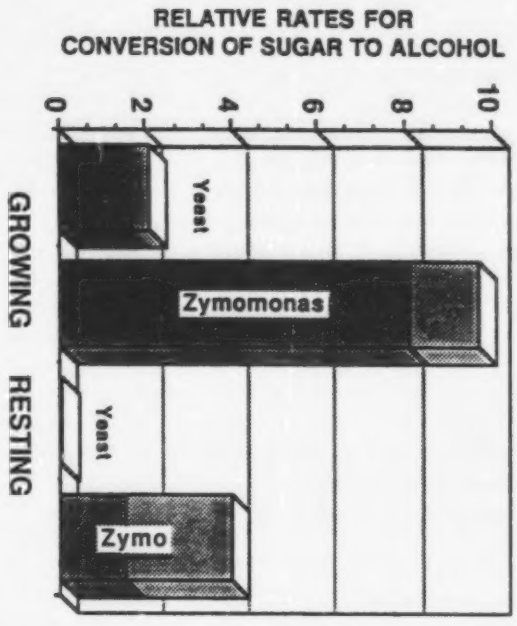
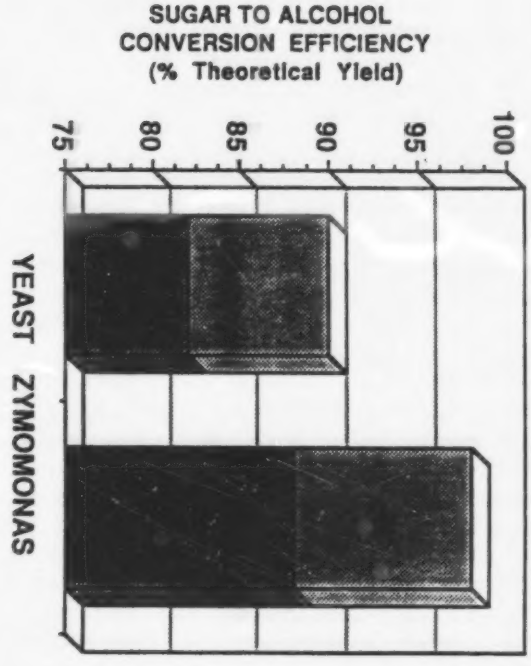

RELATIVE RATES FOR
CONVERSION OF SUGAR TO ALCOHOL
0
2
4
6
8
10
GROWING
Yeast
Zymomonas
RESTING
Yeast
Zymo


SUGAR TO ALCOHOL
CONVERSION EFFICIENCY
(% Theoretical Yield)
75
80
85
90
95
100
YEAST
ZYMOMONAS

CANPAC '88

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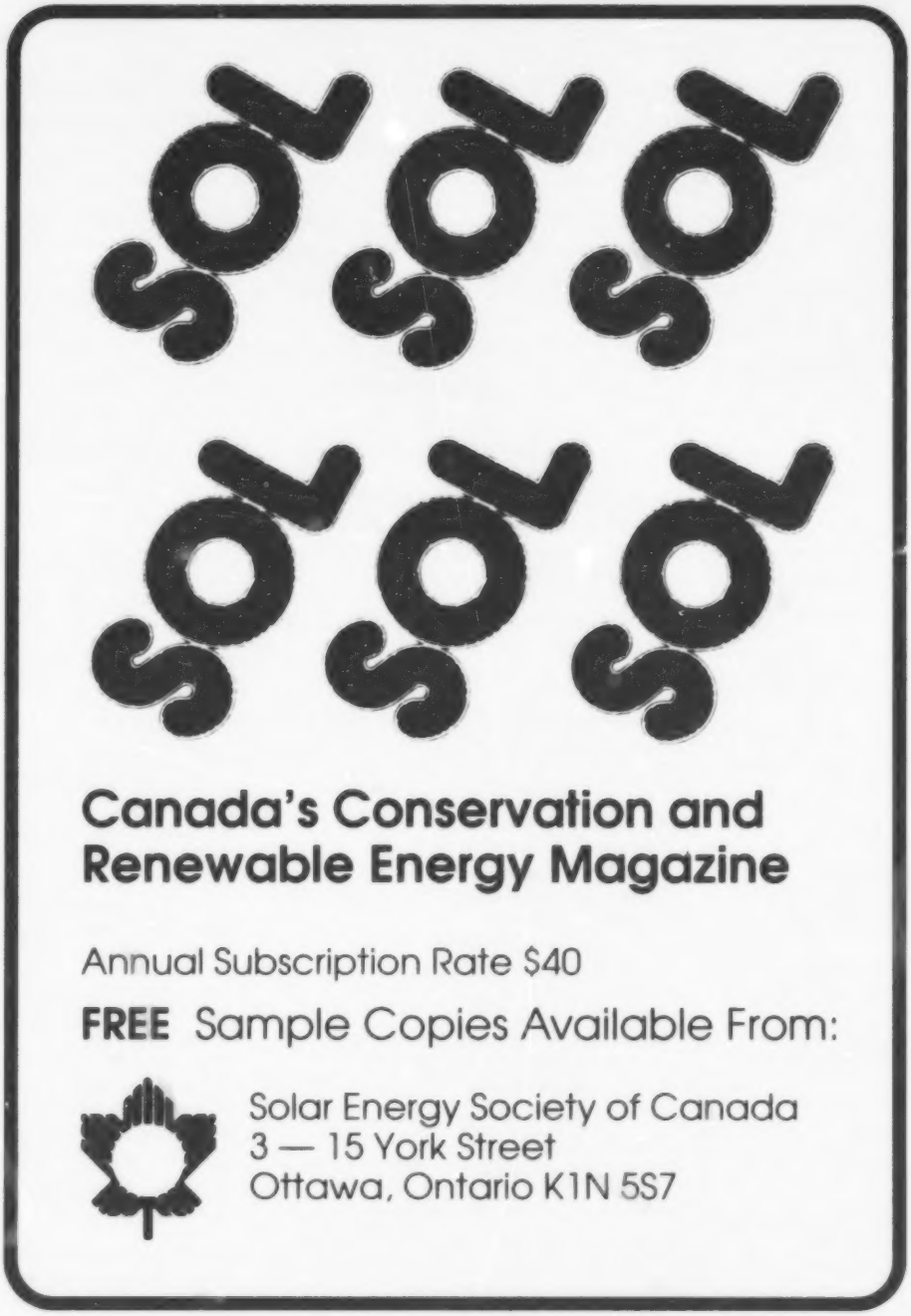

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